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SOME PRACTICAL CONSIDERATIONS IN TESTING FOR GENETIC LINKAGE IN SIB DATA

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The detection of an association between two inherited characters in family data has sometimes erroneously been interpreted as evidence of genetic coupling or linkage. To establish linkage an equivalent degree of dissociation between the two characters must be demonstrated in the families where the genes which underlie the characters are in repulsion. It has, for example, been asserted that the coincidence of retinitis pigmentosa and polydactyly in certain sibships may be due to the coupling of two genes, one of which underlies the retinal changes and the other the polydactyly (Cockayne, 1935). This hypothesis will be rendered plausible only when sibships are discovered in which polydactyly occurs in just those sibs who are free from retinitis pigmentosa. Otherwise the most likely explanation is that a single gene is responsible for both abnormalities. If an observed association between two characters is imperfect, as is usually the case, this incomplete concomitance need not be interpreted in terms of crossing over. Variation in the expression of the same gene in different members of a population and even among members of the same sibship is common in human data.

It is of some interest to examine the consequences of different types of association of genetic characters. In the first place, if two characters are due to the same gene, positive correlation is observed whether subjects are chosen within specified sibships or selected at random from the general population. The correlation, moreover, is independent of whether or not a physiological connection between the peculiarities can be traced. This type of association must be distinguished from that due to independent genes which have a racial or local grouping. In Holland (Van Herwerden, 1930), for example, a

positive correlation, likely to be due to racial grouping, was noted between the possession of agglutinogen B and dark hair color in the general population. In such instances, although the traits are associated in the general population, there will be no correlation between them within the sibships.

Two characters will be found to be negatively correlated within sibships and also in the general population if they are due to allelic genes. This is because the presence of one allelic gene excludes the presence of any other allele. For example, the fact that blood group AB is found to be much less frequent than it should be on the assumption that A and B are independently assorted is, by itself, strong evidence that A and B are allelic genes. Finally it is possible for the same

TABLE I

Relationship Between Two Characters	Correlation Between the Two Characters	
	In the General Population	Within the Sibship
Independence	0	0
Due to same gene	+	+
Racially grouped	+	0
Due to allelic genes	—	—
Physiological compensation	—	—
Genetic linkage	0	+ or —

gene to have effects of a physiologically compensatory nature. Thus, for instance, head shape may vary according to genetic constitution in persons whose head sizes are of the same magnitude: length and breadth of the head may thus be found to be negatively correlated both in sibships and in the general population.

When dealing with the metrical characters which have multiple genetic backgrounds, the possibility of finding conditions which closely simulate linkage in sibships must not be overlooked. If the two characters are totally uncorrelated in sibships the danger of making a mistake is slight. Even so, it is theoretically possible for concomitant and compensatory variations which are not in any way due to genetic linkage to coexist. In Table I the types of association and dissociation which may be mistaken for linkage are set out.

The peculiar feature of genetically linked characters is that they are equally likely to be positively or negatively correlated within single sibships.

The simplest way of testing for genetic linkage between dominant and recessive characters (Penrose, 1935) is to classify all the pairs of sibs in the available data. A 2 × 2 table is compiled in which each pair is entered according to whether its members are like or unlike with respect to the two test characters. A significant deviation from proportionality in such a table can be caused by linkage between the two characters. A similar deviation can also be caused by any of the situations discussed in the paper which give rise to a positive or negative association. These possibilities must therefore

TABLE II

		Character A		
		Like	Unlike	Total
Character B	Like	x	y	x + y
	Unlike	z	w	z + w
	Total	x + z	y + w	t

always be examined before claiming a positive result in any linkage study.

If the numbers in one or more of the cells in the 2 × 2 table are small, the exact test for significance of a deviation from proportionality can conveniently be applied (Fisher, 1934). An estimate of the recombination value of the two genes can be obtained from the 2 × 2 table by calculating the function ϕ, from Table II, by the following formula

$$\phi = \frac{xw - yz}{(y + w)(z + w)}.$$

If there is no crossing over, ϕ has the maximum value of $\frac{1}{2}$ with common characters and of $\frac{1}{3}$ if one or both characters are rare. When there is random assortment, $\phi = 0$. The standard error of ϕ is approximately $\sqrt{1/w - 1/t}$ and so the statistical value of the result depends mainly upon the

number of pairs of sibs unlike for both the characters. Unless the investigator is fortunate enough to obtain a small sample of data in which ϕ happens to have an unusually large value, no significant positive result is to be expected unless more than 100 pairs are classified. If sibships in which one of the characters does not occur are left out of the reckoning, there is no loss of information because these sibships cannot contain any pairs unlike in both characters. In practice it is convenient to select sibships by the presence of a comparatively rare dominant or recessive trait in at least one member; tests for linkage are then made with other traits which are found distributed in these sibships. If the second test factor has a fairly high gene frequency in the general population, the cells x, y, z and w in the 2×2 table will all be of the same order of magnitude. In this case significance of a deviation from proportionality can be safely examined by the symmetrical function χ^2, by the formula

$$\chi^2 = \frac{(xw - yz)^2 \, t}{(x + y)(x + z)(z + w)(y + w)} .$$

If the numbers in the four cells are exactly equal in magnitude this test is equivalent to applying Fisher's u_{11} function to the data.

The method of classifying like and unlike pairs of sibs needs amplification if the data concern characters which have more than two alternative values. Data analyzed by Burks (1937) concerning tooth deficiency and hair color are of this type. Metrical characters can be dealt with by differences in sib pairs (Penrose, 1938); they can also be simplified by choosing a point in the scale so that every individual can be classed as greater or less than a given value. It is not permissible to classify sibs so that unlikenesses of more than one kind are grouped together. With multiple alleles care is also needed. Suppose, for example, that in a certain family there are four sibs, as follows: M, A; N, A; MN, a; and MN, a. Here M and N. represent blood agglutinogens and A is a rare recessive trait. The sibships can be scored for like and unlike pairs for the two characters N and A or for M and A separately. The result is the same in either case (Table III) and correctly indicates free assortment of the characters.

If an attempt is made to group like and unlike pairs without specifying two alternatives and only two, a different distribution is obtained (Table IV). There is now a positive deviation from proportionality. The correct way to compile this table is to

TABLE III

		A	
		Like	Unlike
M.....	Like.....	1	2
	Unlike.....	1	2

TABLE IV

		A	
		Like	Unlike
M, N, or MN....	Like.....	1	0
	Unlike.....	1	4

TABLE V

		A	
		Like	Unlike
MN.....	Like.....	1	0
	One degree of unlikeness.....	0	4
	Two degrees of unlikeness.....	1	0

distinguish between unlikeness of M and N (two degrees) and unlikeness of MN and M (one degree). The table should be a 2×3 table (Table V) in which symmetry is again established.

The method of counting like and unlike pairs for characters which can take several alternative values will give rise to misleadingly positive results if uncritically applied.

The search for interrelationship due to genetic linkage between psychological factors has been suggested by Price (1937). The same care is needed in selecting suitable mental factors for testing as in choosing physical characters. Only abilities which are uncorrelated can be rightly chosen for the test. If the simple method of like and unlike pairs is to be used, each sib must be scored for presence or absence of each given quality.

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Van Herwerden, M. A., and **Boele-Nyland, Th. Y.** 1930. Proc. Kon. Akad. Wet. 33: 659.

Schizophrenia

The author of this book, while now connected with the New York State Psychiatric Institute and Hospital, was formerly with the Herzberge Hospital in Berlin. While there he made an intensive study of the schizophrenic cases admitted to the hospital during its first ten years of existence. These comprise 1087 proband cases, diagnosed and proved to be schizophrenics beyond the possibility of doubt. In addition there were carefully studied 3279 husbands, wives and parents of these probans, 3384 direct descendants, 3920 siblings and 2194 nephews and nieces. These individuals were as far as possible personally interviewed. The interviews were supplemented by the extensive registry and police records. The results have been embodied in the present book.

Believing that the demonstration of a genetic basis for schizophrenia would not result in a fatalistic nihilism towards clinical therapy and prophylaxis, but rather would put therapeutic procedure on a sound biological basis, the author made a careful genetic survey of his material. He concludes that schizophrenia is dependent upon a recessive factor, with a penetrance of about 70%. The eugenic and clinical implications of these findings are discussed at considerable length. He also concludes that there is a genetic relationship between the tendency to schizophrenia and the heredito-constitutional susceptibility to tuberculous infection, and he further suggests that the common basis for these two predispositions lies in a hereditary functional weakness of the reticulo-endothelial system. Seventy-six tables and many detailed case records make up the body of the book. A glossary and a bibliography are appended.—*L. H. S.*

The Genetics of Schizophrenia, by F. J. Kallman. xvi + 291 pp. New York, J. J. Augustin, 1938. $5.00.

Worm's-eye Viewpoint of Life

This is a simple, straightforward, very informal account of the phenomena of life, told by a biologist renowned for his penetrating researches into heredity and sex-determination. The worm Ascaris provides the theme of the story, but only the theme, there being many delightful side-excursions into other regions of the animal world and into the author's personal reminiscences. Almost the book could be recommended as a text. At any rate it should be required reading for all students of zoology. It provides a fresh viewpoint and a personal approach which might well be incorporated into text books.—*L. H. S.*

Ascaris: the Biologist's Story of Life, by Richard Goldschmidt. ix + 390 pp. New York, Prentice-Hall, Inc., 1937. $3.25.

A GRANODIORITE STOCK IN THE CASCADE MOUNTAINS OF SOUTH-WESTERN WASHINGTON

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INTRODUCTION

The presence of a body of granitic rock near Silver Star Mountain in the Cascade Range of south-western Washington has been known to prospectors and mining men of the region for more than fifty years, but no material on the geology of the immediate region has been published. Allen[1], in an unpublished thesis, described the granitic rock as a quartz diorite and called the mass "Silver Star Formation" after the highest peak in the area. Any work that may have been done in connection with mining operations within the area is not publicly available.

The aims of the study summarized in the following paper were, in the main, twofold: (1) to map, both areally and structurally, the intrusive and as much of the surrounding rocks as necessary to determine the time and mechanics of intrusion, and (2) to determine the petrographic character and the petrologic history of the intrusive body and its surrounding rocks.

The work was made possible by a grant from the research fund of the Ohio Academy of Science and was greatly furthered by the able work of the writer's field assistant, Mr. R. H. Howe. The co-operation and assistance given by the U. S. Forest Service men of the Columbia National Forest is also greatly appreciated.

[1]Allen, J. E. "Contributions to the Structure, Stratigraphy, and Petrography of the Lower Columbia River Gorge." Univ. Oregon M.A. Thesis, 1932.

Suggestions made, both in the field and in the preparation of the manuscript, by Dr. J. L. Rich have been particularly helpful.

Location. The area examined lies in the western portion of the Middle Cascades about twelve miles north of the western end of the Columbia River Gorge. It consists of a rectangle eight miles north-south by five miles east-west, the south-west corner of which is that of Township 3 North, Range 5 East, Willamette Meridian. The area thus described comprises forty square miles, the northern three-quarters of which are within the Columbia National Forest boundaries.

The region may be reached from Portland by U. S. Forest Service roads connecting with the state highway system of Washington at either Hemlock or Yacolt.

Drainage. The area is drained by the headwaters of both the Washougal River and the South Fork of the Lewis River. The Washougal is a south flowing stream entering Columbia River near Camas, Washington. The Lewis flows to the west, is joined by the North Fork, and enters the Columbia near Woodland, about thirty-five miles downstream from the mouth of the Washougal. The headwaters of these two streams have dissected the area in a dendritic manner to a mature stage with a relief of from 2500 to 3000 feet. A divide, along which are located the highest peaks of the immediate area, separates the opposing headwaters of the Lewis and the Washougal. This divide trends from the north-east corner of the area in a direction a little west of south to the summit of Bluff Mountain, in section 16, where it turns at right angles and trends east-west to the summit of Silver Star Mountain.

The greatest precipitation occurs in the winter months and is, in the higher portions of the area, frequently in the form of snow which forms enormous drifts in the deeper canyons. These drifts linger till past mid-summer in most years and are largely responsible for the perennial character of many of the smaller streams near the heads of the canyons which would otherwise be without water in the late summer.

Since the destruction of the forest cover in the great fires of 1902 and 1929 the runoff has been much more rapid than formerly. The effects of this increased runoff are shown to best advantage on steep soil-covered slopes by the development of young gullies, and, in some cases, by complete removal of the thin soil mantle. Another noticeable effect is the increased severity of the spring freshets that accompany the warm spring

rains. Quantitative data on this increased runoff can not be obtained as no figures for the precipitation or runoff in the immediate area are available.

Topography. As was stated under the heading of drainage, the region is a maturely dissected plateau, largely of lavas, with a relief averaging close to 2000 feet and locally reaching a maximum of 3000 feet. The main divide between the Lewis and Washougal drainage basins attains elevations as great as 4400 feet A. T. and has saddles, where strong opposing tributaries have been active, as low as 2900 feet A. T. The general eleva-

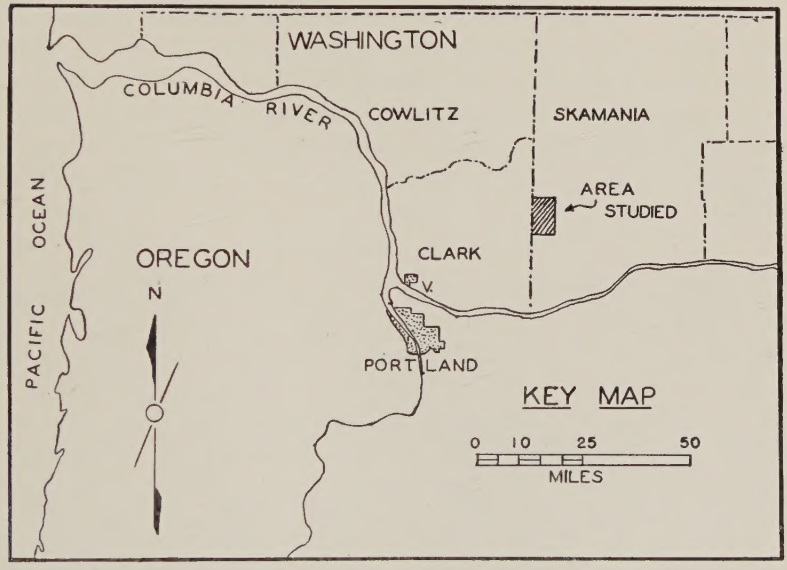

Fig. 1. Location Map.

tion is, however, near 3200 feet A. T. From this main divide branch long steep spurs separating the canyons and the smaller gullies occupied by the individual headwaters. These spurs are very steep, sloping from the elevation of the main divide down to the level where the two streams join; the slopes of the spur crests often are as great as 2000 feet per mile. Their sides are more precipitous, in some cases being vertical cliffs from a few tens of feet up to 1200 feet in height, but more commonly being live talus slopes resting at the angle of repose. These talus slopes, best developed on the granodiorite, cover a large portion of it and are in a few instances more than a mile in length.

At the heads of some of the larger canyons are small cirque-like basins in whose bottoms are depressions as much as seventy-five feet deep and 150 yards in diameter. These are separated from the head of the canyon proper by a rock rim or lip. Often these basins are occupied by small tarns, and snowdrifts persist in a few until late summer. No glacial striae were found on the rock lips; and, consequently, these basins are believed to be the result of erosion by small glaciers, not extensive enough to have moved very far out of their cirques.

The summits of the ridges when viewed from one of the higher peaks exhibit the same strikingly accordant skyline that is evident in the Cascades further north. This accordance has been treated by Willis,[2] Russell,[3] Smith,[4] and others as representing the trace of an old erosion surface called by them the Cascade peneplain. Regardless of whether or not it represents a true baseleveling, this accordance of summits as viewed on the skyline is one of the striking features of the topography of the region.

AREAL GEOLOGY

Eagle Creek Formation. The rocks of this area fall naturally into three distinct lithologic units. The oldest of these is the Eagle Creek formation (Warrendale formation of Hodge[5] and others) of probable Oligocene age (now considered lower Miocene by Chaney[6]) consisting of volcanic tuffs and breccias, bajada conglomerates, and minor amounts of intercalated andesitic lava flows near the top of the formation. The Eagle Creek is typically exposed in the central portions of the Columbia River Gorge where it has been described by Chaney[7] and Hodge[5] and is also widely exposed in its numerous variations in the greater part of the Washougal basin. This formation outcrops along the eastern margin of the area under consideration, especially good exposures being noted in parts of sections 21,

[2]Willis, Bailey. "The Physiography and Deformation of the Wenatchee-Chelan district, Cascade Range." U. S. G. S. Prof. Paper 19, pp. 41–95, 1903.

[3]Russell, I. C. "A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington." U. S. G. S. 20th Ann. Rpt., pt. 2, pp. 83–210, 1900.

[4]Smith, G. O. "Contributions to the Geology of Washington: The Geology and Physiography of Central Washington." U. S. G. S. Prof. Paper 19, pp. 9–38, 1903.

[5]Hodge, E. T. "Progress in Oregon Geology Since 1925." Northwest Science 6: 44–53, June, 1932.

[6]Chaney, Ralph W. Personal communication, April, 1936.

[7]Chaney, Ralph W. "The Flora of the Eagle Creek Formation." Chicago Univ. Walker Mus. Cont., Vol. 2, No. 5, pp. 115–181, 1920.

22, and 28 near the headwaters of Dougan Creek. Exposures of the Eagle Creek formation also occur in the canyons of Silver, Bluebird, and Bear Creeks along the eastern margin of the area; but, in these basins, they were not differentiated on the map from the overlying Skamania andesites.

The Eagle Creek as exposed within the mapped area consists mainly of cream colored vitric tuffs which usually weather to a yellow or white colored soil. Varicolored tuffs, usually green or red, are also found as are some greenish and purplish breccias. The tuffs may pass through the complete range of color within a distance of twenty-five feet along the strike. The lack of assortment and usual lack of bedding of any regular nature within these tuffs suggest a subaerial mode of accumulation. At many places, however, the tuffs and breccias have been reworked by streams; and the bedding shows, in these cases, that accumulation was governed by fluviatile and occasionally lacustrine conditions.

Skamania Andesites. The Eagle Creek beds are overlain by a thick series of andesites among which are intercalated minor amounts of breccia and other pyroclastic material. Within the area the contact is nowhere definitely exposed, although in many places it can be approximated within five feet. East of the mapped area, in the Washougal basin, the andesites overlie the Eagle Creek in places disconformably and in other places with a distinct angular unconformity representing a period of considerable erosion. At still other localities, notably on the east edge of the mapped area the andesites interfinger with the tuffs suggesting at least partial contemporaniety or overlapping of the deposition of the tuffs and the extrusion of the andesites.

These andesites compose the bulk of the country rock into which the granodiorite stock forming the subject of this paper was intruded, and are the most wide spread of the formations within the mapped area. They are in the form of rather thin and extensive flows that were probably extruded in a very fluid form. Locally these flows may have had rather high initial dips, a fact that complicates quantitative determination of later folding. In the lower two-thirds of the series the flows are mildly folded—the maximum dips recorded being about thirty-five degrees. This figure rarely exceeds ten degrees, the steeper dips being noted in only a few places near the contact with the intrusive rocks. The upper third or about 800 feet of these flows, exposed only on the upper portion of Silver Star Moun-

tain, is nearly flat lying, the maximum dips recorded being two degrees in a westerly direction. This upper portion has also suffered less alteration than the lower partially propylitized andesites.

These lavas support most of the steep cliffs within the area, also most of the higher peaks such as Bluff and Silver Star mountains as well as most of the higher portions of the divides. They are the most conspicuous and best exposed rocks in the area and over wide areas in adjacent portions of Skamania County. For this reason the name Skamania is proposed for this series of andesites.

No definite age has been assigned to this series of lavas, but, in the opinion of the writer, they are the probable equivalent of the widespread Keechelus series so prevalent in the Cascades a few tens of miles to the north. This opinion is based on the following facts: (1) the petrographic character of the andesites in the mapped area and that of the Keechelus as described by Coombs[8] and others is very similar; (2) the Columbia River Basalts exposed in the Columbia River Gorge appear to abut against the lower portions of the Skamania andesites; therefore, these andesites, in the lower part, must be pre-Columbia basalt or, in other words, pre-middle Miocene which corresponds with the supposed age of the lower Keechelus lavas as suggested by Warren;[9] and (3) the Skamania andesites are divided in the same manner as the Keechelus into an upper and lower division. As in the Keechelus, the lower division of the Skamania has undergone more folding and metamorphism than the upper division.

Lavas later than the andesites of the Skamania series occur as intracanyon flows in the canyon of the Lewis River four miles west of the area and in the canyon of Wind River a few miles to the east. Those in the Lewis River near Sunset Guard Station have been trenched by the river in a narrow gorge exposing old andesitic and dioritic stream gravels cemented together by the andesite of the late flow. The age of these intra-canyon flows is probably Pleistocene.

Silver Star Granodiorite. The third lithologic unit within the area is a stock of granodiorite with subordinate amounts of

[8]Combs, H. A. "The Geology of Mt. Rainier National Park." Univ. Wash. Pub. in Geology, Vol. 3, No. 2, pp. 131–212, 1936.

[9]Warren, Walter. "Tertiaries of the Washington Cascades." Pan-Am. Geologist, Vol. 65, No. 4, pp. 241–247, 1936.

augite diorite and quartz diorite near the borders of the mass. The stock is an elongate body about ten miles long and varying in width from one and one-half to two and one-half miles. Its long axis trends north twenty degrees east. Its walls are very steep as proven by the fact that very deep canyons cutting into the country rock a short distance from the walls do not expose any mappable areas of intrusive rock. Small spots of granodiorite were observed in Star Canyon and in the canyon of Dougan Creek but were not mapped. The southern boundary of the stock, extending to the south for a distance of about a mile, was traced but not in enough detail to be drawn on the map.

This stock cuts the Eagle Creek formation and the lower portions of the Skamania andesites, producing contact metamorphic phases in both formations and sending small dikes and stringers of granodiorite and aplite into both the tuffs and andesites. The upper third of the andesites does not seem to have been intruded by this granodiorite. At least no dikes or other evidences of intrusion cut the upper andesites and they have not been subjected to the degree of propylitization that characterizes the lower portions of the series. It would thus appear that there has been some time interval between the extrusion of the lower and the upper divisions of the Skamania series. During this interval the intrusion of the granodiorite occurred.

Swarms of xenoliths near the contacts with the andesite and larger inclusions of tuffs and andesites in the upper portions of the intrusive rock indicate that stoping processes had a role in the emplacement of the mass. Some of these inclusions are large enough to have been roof pendants of considerable size. These inclusions are quite thoroughly metamorphosed, usually to hornfels.

The granodiorite is strongly jointed—a fact that allows frost action on the high peaks, such as Little Baldy, to rive the outcrops into rhombic and platey fragments with the consequent production of the long talus slopes previously mentioned. Good outcrops occur only in the stream bottoms and occasional cliffs not yet covered by talus. The boundaries of the stock, where drawn in dotted lines, can be approximated within a very few feet; but the actual contact is covered. This lack of suitable outcrops is also responsible for the paucity of structural measurements.

PETROGRAPHY

Eagle Creek Formation. The Eagle Creek formation, as exposed in the area, consists of vitric tuffs usually white or cream colored, and, less commonly, of greenish and reddish hues. The color, in most cases, seems to depend upon the character of the oxidation of the iron compounds within the glass at the time of formation. The material composing these tuffs ranges from partially kaolinized shards less than 0.05 mm. in diameter to coarse fragments of vesiculated pumiceous material up to three inches in diameter. This pumiceous material has been indurated and made resistant by compaction and cementation. The cement in the majority of cases is silica, although enough kaolin is present in most cases to also act as a cement.

In places where the tuffs have been subjected to hydrothermal solutions emanating from the intrusive body they have been entirely replaced by silica forming a very resistant quartz rock in which are preserved the shard structures of the original tuff. Good outcrops of this silica rock occur in the low saddle in section 21 just south of Bluff Mountain.

Skamania Andesitic Series. The rocks composing this series consist, in the main, of gray porphyritic andesites with subordinate amounts of tuffs and breccias. The pyroclastics are petrographically very similar to the coarser phases of the Eagle Creek, possibly a little more pumiceous.

The andesites of the lower portion of the series are characteristically gray or greenish-gray in color and are nearly always porphyritic, the phenocrysts being striated grayish-white feldspar. The flows in this portion are usually much jointed with epidote and other minerals frequently developed within the joint cracks.

Examination of thirty-five slides from the lower portion of the andesite series brings out the following general characteristics. All sections examined were porphyritic with phenocrysts of corroded and markedly zoned plagioclase embedded in a pilitic to intersertal and, infrequently, diabasic groundmass of plagioclase laths, granular augite, and anhedral magnetite, together with varying amounts of chlorite and similar minerals developed from the ferromagnesian constituents. The phenocrysts range in size from 1 to 6 mm. and average about 3 mm. in diameter. They are blocky and exhibit a marked tendency

toward a glomeroporphyritic habit. Their composition ranges from An 50 to An 30 with the average being close to An 35. Where zoned the core has the more basic composition. Usually the composition becomes more acid outward with each zone although rarely some reversals of zoning do occur. Small veinlets of orthoclase are developed in fractures traversing these phenocrysts especially in those sections made from specimens taken from close to the intrusive body. Twinning is after the albite, Carlsbad, and pericline laws with all three commonly developed on one individual. These phenocrysts form from 20 to 35 per cent of the rock.

The plagioclase laths in the groundmass vary in size from 0.01 mm. up to 0.5 mm. in length averaging about 0.3 mm. They vary in composition in the various flows from basic to medium andesine and in one of the most basic of the flows are an acid labradorite. Twinning is commonly after albite and Carlsbad laws, pericline twinning being rare. Often these laths are arranged in a marked fluxion structure. These second generation feldspars comprise from twenty-five to forty per cent of the rock.

The ferromagnesian minerals are nearly always altered to chlorite and similar minerals, but, where fresh, are anhedral grains filling the interstices between the feldspar laths. These minerals may be either augite or hornblende—usually augite and in rare cases hypersthene. There may have been considerable amounts of hypersthene in some of the rocks but it has since become chloritized. A very few thin sections show relicts of what were probably hornblende phenocrysts.

The augite of the groundmass occurs as anhedral grains rarely exceeding 0.05 mm. in diameter, is pale yellow in plane light, and sometimes shows a faint pleochroism. N_m averages about 1.69. This augite makes up 15 to 25 per cent of the rock. Magnetite, in the form of small anhedral grains and dust, is scattered through the groundmass and makes up about ten per cent of the rock. Epidote developed within the plagioclase phenocrysts and chlorite from the pyriboles sometimes totally destroy the former minerals.

The upper division of the Skamania andesites is characterized by fresher rocks of the same general types as those described for the lower division. These rocks are, however, generally more vesicular and in some cases have partially hyaline groundmasses. The rocks are in thin flat-lying flows exposed only on

the upper portions of the main mass of Silver Star Mountain. A few quartz and carbonate veins cut these flows, some of the vesicles are filled with chalcedony or dolomite, and some of the ferromagnesian minerals in the groundmass are chloritized. Otherwise the rocks are nearly fresh as contrasted with the propylitized rocks of the lower division.

Microscopic examination of 15 slides from these flows shows the following characteristics. Except in a few holohyaline flows of little importance all of the flows are porphyritic with phenocrysts of medium andesine averaging about 3 mm. in length. These phenocrysts are hypidiomorphic, exhibit strong zoning, marked corrosion, and a tendency toward a glomeroporphyritic habit. Combined Carlsbad and albite twins are very common. These phenocrysts comprise from 15 to 30 per cent of the rock.

The groundmass consists of a pilitic, intersertal, or, less commonly, a diabasic aggregate of plagioclase laths, anhedral grains of pyroxene and magnetite, and, commonly, small amounts of glass. The feldspar laths range from acid labradorite to medium andesine with basic andesine being the average composition. The pyroxene is usually augite and much less commonly hypersthene. Grains of pyroxene averaging less than 0.03 mm. fill the interstices between the feldspar laths which range from 0.01 to 0.65 mm. in length. The second generation plagioclase comprises from 25 to 40 per cent of the rock, the pyroxene from 15 to 25 per cent, and the anhedral magnetite from 5 to about 12 per cent. Fluxion structure, aligning the phenocrysts and the second generation laths, is usually present and is developed to a marked degree in some of the sections studied.

Silver Star Granodiorite. The rock composing this body consists of a mass of granodiorite with subordinate amounts of augite diorite and quartz diorite developed near the periphery of the stock. Aplite dikes and hydrothermal rocks rich in quartz, tourmaline, and sericite are also developed locally within the mass.

The granodiorite is a light colored aggregate of white plagioclase, sometimes tinged pink with the development of orthoclase, clear colorless quartz, and black to greenish biotite and hornblende crystals the color of which depends upon the degree to which chloritization has progressed. In most cases, the minerals can be distinguished megascopically, the grain size often being as large as 6x9 mm.

Microscopically the rock exhibits a holocrystalline granitic texture with the minerals, both light and dark, not uncommonly

aligned in a sub-trachitoid structure. In some instances, the larger plagioclase crystals impart a sub-porphyritic appearance to the rock.

The plagioclase is hypidiomorphic, generally corroded and strongly zoned. The composition of the cores averages basic to medium andesine, each zone becoming richer in Ab to an outer zone of albiclase, or, less commonly, albite. Many of these plagioclases have a final rim of orthoclase. This orthoclase also commonly fills fractures developed in the plagioclase crystals. The plagioclase comprises about 55 per cent of the rock.

10 to 25 per cent of the rock consists of interstitial and anhedral orthoclase—in some instances as clear as the quartz, which it closely resembles optically—but more generally "dusty" with sericite.

Clear anhedral quartz shares with the orthoclase the interstices between the earlier formed minerals. The two are commonly intergrown in a myrmekitic intergrowth showing contemporaniety of crystallization. The quartz granules average from 0.5 to 1.2 mm. and make up from 10 to 25 per cent of the rock.

The dark minerals may be uralitized pyroxene, or, more commonly, hornblende or biotite with varying amounts of chlorite and secondary dusty magnetite. A little subhedral magnetite was developed early. These dark minerals are crowded into the interstices between the plagioclase feldspars and make up about 10 per cent of the rock. The biotite, where developed, is a lustrous black variety with 2V estimated at about 5 or 6 degrees and is strongly pleochroic, the formula being X pale yellowish brown, Y reddish brown, and Z very dark brown to black. Inclusions of apatite and of titanite are developed in the plagioclase and to a lesser extent in the quartz.

The more basic phases, as exposed at many places near the walls of the stock are characterized by more lath-like plagioclase crystals, little or no quartz and orthoclase and larger amounts of pyroxene, usually augite. The plagioclase is ordinarily basic andesine. These more basic rocks make but a very small percentage of the total in the stock. Intermediate between these and the true granodiorite is a diorite very similar to the more basic diorite but with 5 to 12 per cent quartz and a little orthoclase.

Aplite dikes developed at a late magmatic stage are composed almost entirely of quartz and pink orthoclase with very small amounts of biotite and of sulfide minerals. Myrmekitic inter-

growth is common and the orthoclase is commonly sericitized or even kaolinized to a considerable extent.

Metamorphic Rocks. The metamorphic rocks in this area are all products of thermal or hydrothermal processes accompanying the intrusion of the stock. The thermal metamorphism at places along the contacts between the stock and the andesites produces hornfelses of sugary grained recrystallized feldspar, augite, and magnetite, with considerable quartz being introduced in some instances. Where this action has been less severe at a distance from the contact, relicts of the original minerals remain, and the hornfels is very poorly developed. At a greater distance the effects become less marked, until, at a distance varying from a few feet to several hundred, the only effect has been a propylitization of the andesites. This propylitization consists, in the main, of the development of epidote and chlorite within the andesites and the introduction of large amounts of pyrite and quartz. The replacement of the tuffs in the Eagle Creek formation by silica was mentioned previously.

Other hydrothermal effects, both within the intrusive and in the wall rocks, consist of (1) epithermal quartz-sulfide veins carrying low values in base metals and small amounts of gold, (2) quartz-tourmaline-sericite replacements occurring in shatter zones and as small veinlets in the granodiorite, and (3) silicification and orthoclasization of areas in the granodiorite apparently after consolidation of the mass.

The genesis of the ore deposits within the area is being studied and reported in a separate paper by the writer's colleague, Mr. R. H. Howe.

The tourmaline-quartz replacements are shown to best advantage in the large shatter zone shown on the map as crossing sections 33 and 34. Solutions rich in boron and silica have bleached the granodiorite and produced a luxullianite rock consisting of quartz, schorlite, and sericite. In some instances, the tourmaline aggregates make up 90 per cent of the rock. Small veinlets of tourmaline in bleached and silicified portions of the granodiorite occur at the mouth of Summit Creek. The tourmaline is of the schorlite variety; N_m being 1.66 and the pleochroic formula X pale brown, Z greenish-black. Basal sections show a very marked zonal growth.

The granodiorite in certain areas within the stock, such as in the north-east portion of section 8 and in the north-central portion of section 21 (in the south part of the area) appears pink in the hand specimen and has a dearth of ferromagnesian min-

erals. The original granodiorite, in these instances, shows evidence of having been replaced by orthoclase and quartz after consolidation of the granodiorite. Remains of some of the original minerals and structures of the normal granodiorite have been observed in a number of thin sections made from this altered rock. It is believed that this rock represents a result of orthoclasization after the main mass had consolidated, the potash and silica being introduced either by hot waters or by gaseous emanations.

PETROLOGY OF THE STOCK

Field observations and examination of about fifty selected thin-sections from the stock shows a distinct gradation in the body from a quartz-free dark colored augite diorite, occurring at places near the borders, to a granodiorite, approaching a quartz monzonite in composition in the more central portions of the stock. No distinct zoning occurs and, in places, the more acid portions of the stock are in direct contact with the wall rocks, but, in a general way, it may be said that the dioritic phases are definitely border phenomena.

If the original magma at the time it was intruded had had the composition of a quartz diorite, it could form a series ranging from augite diorite near the borders to the quartz-orthoclase aplite dikes developed at a very late magmatic stage by the process of fractional crystallization. If, however, a magma with a composition essentially that of a granite was intruded into a country rock consisting mainly of andesite by processes involving stoping and assimilation, a similar basic border could also be produced.

Samples taken from the acid central portion in section 33 and from the wall phase in section 16 for chemical analysis resulted as follows:

	Acid Phase	Basic Phase
SiO_2	65.90	58.07
Al_2O_3	15.72	16.54
FeO	3.05	4.26
Fe_2O_3	1.11	2.47
TiO_2	.45	.61
MnO	.06	.17
CaO	4.78	7.32
MgO	2.39	4.94
K_2O	1.94	1.34
Na_2O	3.62	3.32
H_2O (—105C)	.16	Nil.
H_2O (+105C)	.76	.70
CO_2	Nil.	Nil.
P_2O_5	.11	.12

F. H. Herdsman, Analyst, Glasgow, Scotland.

These analyses were plotted on a diagram with the analyses of the Mount Stuart and Snoqualmie granodiorites published by G. O. Smith[4], an augite diorite from Bohemia, Oregon, and a granite from Nimrod, Oregon, published by Buddington and Callaghan[10]. All of these analyses are from intrusives of a nature similar to the Silver Star stock, in the same belt in the Cascade Mountains, and probably nearly of the same age. A fairly representative variation diagram for the Cascade intrusives of this type was obtained (Figure 2). The alkali-lime index for the series of analyses used in this diagram is 62.5 which compares with 61.6 reached for the Cascade intrusives of Oregon by Buddington and Callaghan.[10] This number definitely places these rocks in the calcic group as defined by Peacock.[11]

If the dioritic border be taken as an early roof or wall phase in the crystallization of the stock then the course of differentiation within the mass can be shown chemically by the diagram. The curves for the decreases in magnesia, iron, lime, and alumina, as well as those for increasing potash and soda with increasing silica follow the same trends for the stock as for the whole Cascade region. This chemical change is shown mineralogically by the increase in the acidity of the feldspars from basic andesine in the dioritic border phases to albiclase and even orthoclase in the granodiorite, by the development of relatively large amounts of free quartz in the more acid phases, and by the change from the pyroxenes of the diorites to the smaller percentages of amphibole and biotite in the granodiorite. The feldspars are almost always zoned with the cores having the more basic composition. This fact shows that in all phases of the stock the early formed crystals were removed from the reacting system by the formation of a more acid zone. As these basic cores were prevented from reacting with the remaining liquid, an acid differentiate would thus be formed.

Xenoliths in all stages of assimilation were noted at many places near the borders of the stock. These range with distance from the contact from angular blocks of fresh andesite to barely discernible ghosts made visible by concentrations of hornblende needles. The andesite clearly has been assimilated by reaction

[4] *Op. cit.*

[10] Buddington, A. F., and Callaghan, Eugene. "Dioritic Intrusive Rocks and Contact Metamorphism in the Cascade Range of Oregon." Am. Journal of Science, 5th ser., Vol. 31, pp. 421–449, June, 1936.

[10] Buddington, A. F., and Callaghan, Eugene. *Op. cit.*

[11] Peacock, M. A. "Classification of Igneous Rock Series." Jour. Geology, Vol. 39, pp. 54–67, 1931.

with the invading magma and the possibility exists that some of the border phases could be the result of contamination of a much more acid magna. Such contamination would of necessity be a localized phenomena and would not greatly effect the course of differentiation within the stock.

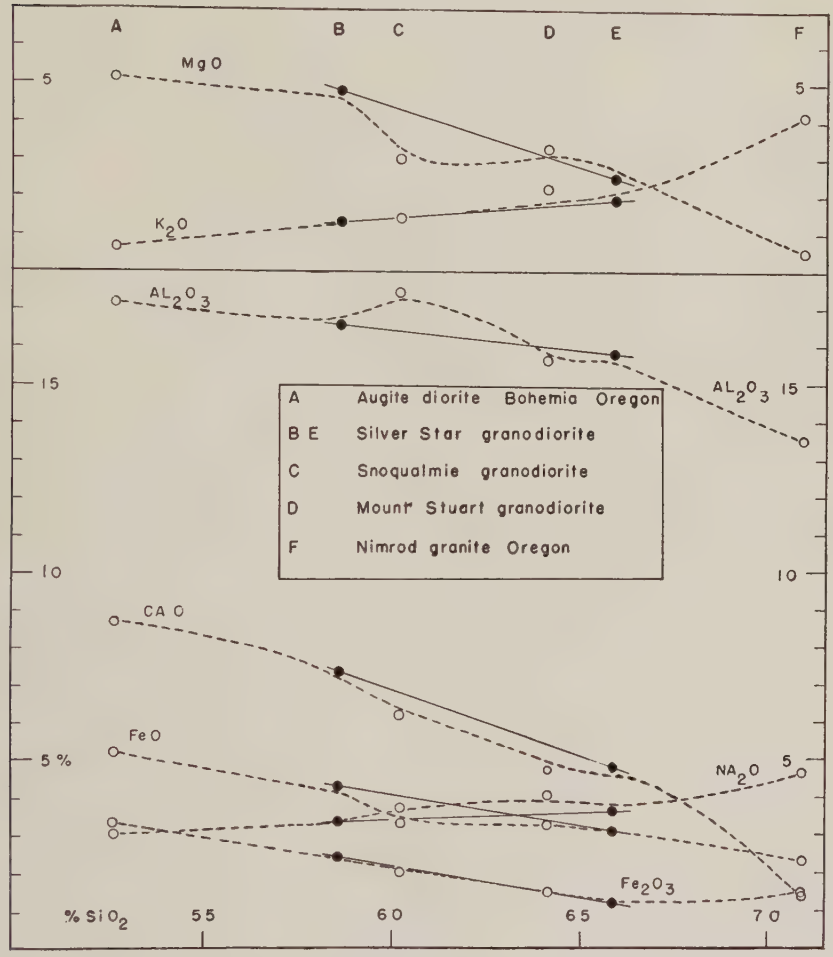

Fig. 2. Variation Diagram for some Cascade Intrusives.

At many places where the basic border of the intrusive is absent the more acid phases are in sharp intrusive contact with the andesite wall rocks. It is believed that at these points portions of the roof including the basic border were stoped into the still liquid acid differentiate and foundered.

GEOLOGIC STRUCTURE

An attempt was made to determine the mechanics of emplacement for this stock using some of Cloos' methods as outlined by Balk.[12] Although a number of measurements were obtained, suitable exposures are so few and so many of these exposures, especially away from the walls, are of so nearly structureless rock that the interpretation of these data should be taken as only suggestive. Although available data were taken from all exposures in the area, so much of the granodiorite is covered by talus that the structural observations necessarily appear somewhat sketchy.

Elongation within the mass is shown in a few places by schlieren, and, less frequently, by a linear parallelism of mineral grains. The best developed of these lineal features occur near the walls and trend parallel or nearly parallel with the local trend of the contacts. The few observations obtained in the central portions of the mass show a rather consistent east-north-east trend varying from north 60 east to north 80 east.

Primary Flow Layers. In a few places along the borders of the mass some of the more resorbed xenoliths and their reaction minerals, principally hornblende, are drawn out in long streaks (schlieren) that are roughly parallel to the walls of the stock. These streaks, in places, form well developed flow layers the strike and dip of which can be measured, but in no case was a consistent pitch of the elements within these streaks apparent. In the north-west corner of section 33 along the Yacolt-Hemlock road a well defined system of streaks and platey structure dips 76 degrees N30W, and in the north-east quarter of section 16 a similar system, less perfectly developed, dips 45 degrees S80E. In both cases, these flow layers dip at rather steep angles away from the stock and under the wall rocks.

In the interior of the stock poorly developed schlieren and elongated inclusions were noted just west of the center of section 4 in the bed of Copper Creek. These layers dip 20 degrees N10W. This last measurement was taken one-half mile east of the west wall of the stock.

Mineral Parallelism. In most of the exposures of the granodiorite the nearly equidimensional character of the mineral grains precludes any development of marked mineral align-

[12]Balk, Robert. "Structural Behavior of Igneous Rocks." Geol. Society Am. Mem. 5, 1937.

ments. However, in places near the walls and near the flow layers mentioned above there exists a linear parallelism of

Fig. 3. Structural Map.

mineral grains, both light and dark, but principally lines formed by the alignment of hornblende needles from the more resorbed

xenoliths near the contacts. The general strikes of these lineal elements are shown on the map near the schlieren noted above and also near the center of section 8 and in the south-west quarter of section 21. In most cases no pitch or dip could be obtained for these linear elements, although those in sections 8 and 16 seem to pitch to the south at high angles.

As was the case with the flow layers, an inspection of the map will show that two principal trends exist. Near the walls the strike of the flow layers and of the mineral parallelism is roughly parallel to the walls, but in the more central portions of the stock the trend swings to the east-north-east.

Joints. Wherever the granodiorite is exposed, in cliffs and in the stream beds, the joints are plentiful. The more persistent of the joint systems, both within the granodiorite and within the wall rocks, are shown on the accompanying map. Within the intrusive there are no extensive well defined systems of joints such as are commonly found in many intrusives which were intruded under pressures great enough to greatly deform the wall rocks. Instead the joints seem to be governed by purely local factors.

Not enough flow structure exists to designate any of the joint systems as "cross joints," but it is worthy of note that a weak general system of tension joints prevails. This system trends approximately parallel with the long axis of the intrusive. The joints in this system are usually vertical or high angle and are frequently filled with aplite dikes. Since they cross the flow lineations that exist in the central portions of the stock at rather high angles, and, since they are followed by the aplitic dikes, they are probably weakly developed cross joints. Near the borders where these joints follow the same trends as the flow structures they would be classed as longitudinal joints. In any case, these high angle joints trending parallel to the walls of the stock indicate a weak doming.

Near the walls of the stock appear sets of gash fractures usually dipping into the intrusive at varying angles and commonly filled with aplite dikes. These fractures are attributed to friction between the wall rock and the moving mass of the intrusive.

Definite sets of conjugate joints exist (1) near the borders of the stock both in the granodiorite and in the country rock, (2) in the wall rocks at a considerable distance, usually from one-half to one and one-quarter miles from the contact, and (3) scattered within the intrusive mass.

Joint systems of the first type intersect at sharply acute angles and are believed to be the result of frictional drag between

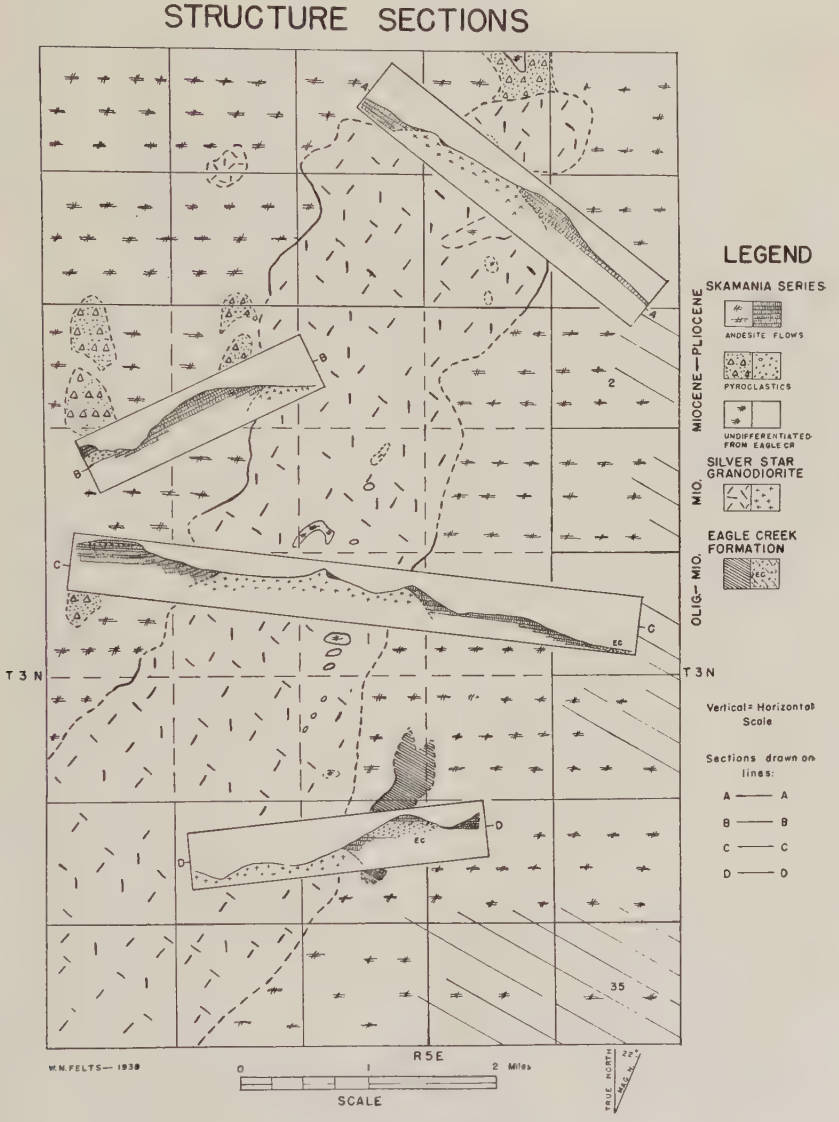

Fig. 4. Structural Sections.

the moving intrusive and the wall rocks. The conjugate joints of the second type intersect at nearly right angles and are believed to be the result of shear due to an almost horizontal

thrust away from the intrusive during emplacement. Conjugate systems of the third type within the granodiorite do not conform to any single system and are probably best assigned to cooling strains. Some of these latter joints are actually faults of small displacement offsetting aplite dikes which fill previously formed longitudinal joints.

In the north-west corner of section 17, and in the north-west portions of section 15 and adjoining portions of section 10 are systems of conjugate joints with a common strike and with dips of 60 degrees to each side. These joints are interpreted as shear planes developed in rigid brittle andesite. Under such conditions, Hartmann's law may be applied to their analysis and the direction of maximum compressive stress would then be determined by a line normal to the line of intersection of the two joint planes and contained in the plane bisecting the acute dihedral angle between the joint planes. In the case of these conjugate joints the direction of this force was vertical.

Conclusions. The above data are believed to indicate that the stock was intruded along a line trending approximately N20E. The lack of serious deformation in the wall rocks and the lack of well defined flow structures and joint systems within the mass of the stock suggest that doming and thrusting aside of the country rock was secondary to stoping in the processes of emplacement, at least in the now visible portions of the stock.

The swarms of xenoliths near the contacts many of which are almost completely resorbed are direct evidence of stoping and assimilation. Just what proportion of the total displacement this process represents is not clear.

The flow layers, where noted, tend to arch toward the center of the stock, the systems of steep joints trending parallel to the long axis of the stock can be interpreted as indicating a weak doming, but analysis of the flow structures and joint systems fails to produce any consistent results. It is believed that this relatively small and shallow intrusive was emplaced principally by stoping processes, at least in its visible portions, with consequent local development of flow patterns and joint systems. Under such conditions the determination of the mechanics of emplacement by the methods of Cloos and Balk becomes much less reliable than in deeper seated bodies intruded under greater confining pressures, under conditions where stoping has not played an important part.

TILLITE AND VARVED SLATE ERRATICS IN NORTHERN RICHLAND COUNTY, OHIO

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University of New Hampshire

INTRODUCTION

Most exposures in Ohio of the Wisconsin till show it to be only moderately pebbly and cobbly, with only occasional boulders. At a few places, however, over areas of one to several square miles, unusual concentrations of cobbles and boulders are evident, both in the till and on the surface. One such concentration is in Blooming Grove Township, northern Richland County, northeastern part of Crestline quadrangle (Fig. 1), where the drift is unusually bouldery and the surface of some fields is so covered with boulders that, as in New England, the boulders must be cleared away before the fields can be plowed. Boulders, which have been dragged out of the fields, are piled up in rows along the fences, roads, and gullies and in one case a stone wall has been built around a barnyard.

Most of the boulders in the drift in Ohio are granite or granite gneiss, but near Rome, in Blooming Grove Township, a high percentage are banded slate. Two tillite boulders were discovered three-fourths mile east of Blooming Grove Township, in Cass Township. Both of these localities lie within the Wabash moraine (Leverett, Pl. 13; White, p. 36), just east of the divergence of that moraine from the more northerly Ft. Wayne moraine.

THE TILLITE BOULDERS

The conglomerate boulders are located one and one-fourth miles southeast of Shiloh, in northwest Section 13, Cass Township, one-fourth mile south of Planktown. They lie at the southeastern corner of a barnyard, at the west edge of State Route 613, 200 feet north of the small stream which crosses the road. The position is shown in Fig. 2.

One boulder (Fig. 3) which lies on the highway right-of-way is 46 inches in the longest dimension and 36 inches in the shortest. It is irregular and subangular to subround in shape. It is made up of particles from 4 inches to sand grain size,

loosely packed, the spaces filled with fine grained crystalline material. The pebbles, which are subangular to subround, are of pink granite, gray granite, pink granite gneiss, gray granite gneiss, vein quartz, greenstone, and dark greenish schist. The matrix is fine grained: in part, dark blackish green material,

Fig. 1. Index map showing location of Blooming Grove Township, Richland County.

now probably mainly chlorite and other ferromagnesian silicates; and in part a crystalline material resembling fine grained arkose.

The second boulder lies 18 feet south-southwest of the first, just outside the line of highway right-of-way. It appears to be more than half underground, but the visible portion measures

58 by 42 inches. It has the same composition as the first boulder, except that its cobbles are smaller and the proportion of matrix higher.

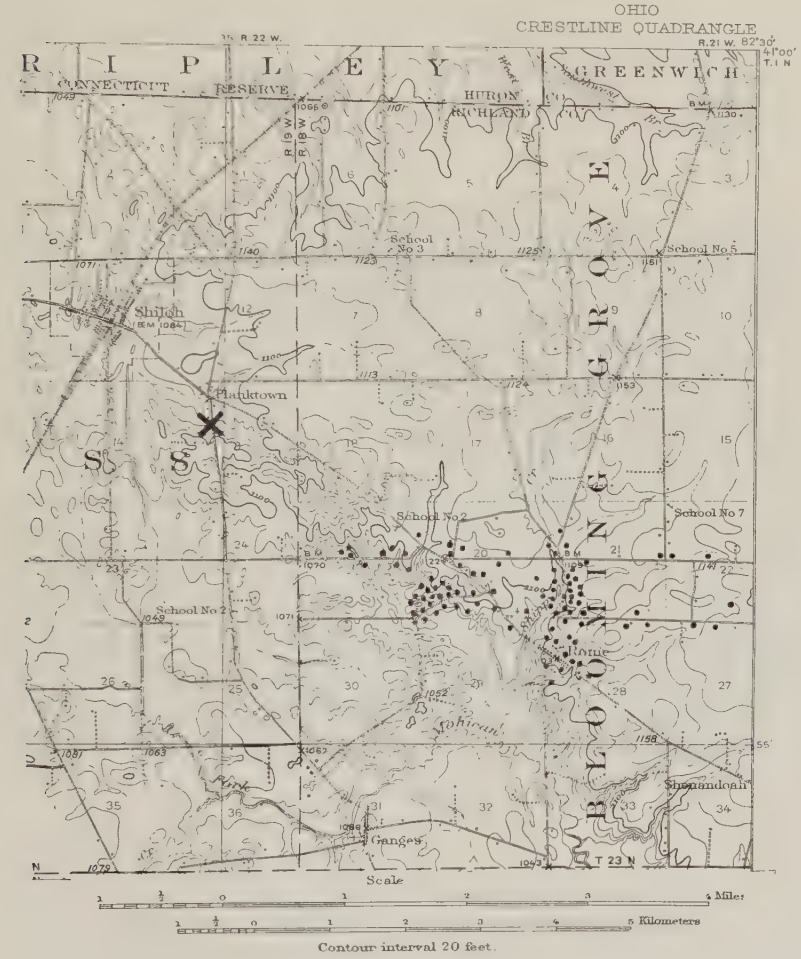

Fig. 2. Northeastern part of Crestline quadrangle. Dots show relative concentration of varved slate erratics. Cross shows location of tillite boulders.

Two almost rectangular blocks of banded slate similar to those concentrated farther east lie between the two tillite boulders. One is 20 by 24 by 15 inches, the other 8 by 10 by 7 inches. The slate is made up of alternating thin dark and light bands. The slaty cleavage is parallel to the bedding planes.

To identify definitely two isolated boulders far removed from original relationships as tillite is difficult or impossible but the writer here interprets them as consolidated ancient (Precambrian) till. The material resembles that of the Squantum tillite, near Boston, Massachusetts, and appears to resemble the Cobalt tillite as described by Coleman (pp. 220–226).

Other boulders of conglomerate which have been interpreted as Precambrian tillite have been found at various places within the drift in Ohio. A large tillite boulder lies in front of Orton

Fig. 3. Tillite boulder on west border of State Highway No. 613, in northwest Section 13, Cass Township, one-quarter mile south of Planktown.

Hall, Ohio State University. Dr. Wilber Stout, state geologist, has preserved in his garden fireplace a small tillite boulder which was dug from the drift in Clintonville (North Columbus). The late Professor Richard C. Lord discovered a large tillite erratic three miles southwest of Gambier, in Pleasant Township, Knox County, about 300 yards west-northwest of the 1194 roadfork which is one-half mile northwest of Graham School. Tillite boulders, while very uncommon in Ohio drift, have been found at widely separated intervals over the state. Professor J. Ernest Carman (personal communication, 1938) estimates that he has seen approximately twenty tillite erratics in his field work in Ohio.

SLATE ERRATICS

A marked concentration of slate erratics occurs in Blooming Grove Township in the vicinity of Rome, as shown in Fig. 2. The spacing of the dots in Fig. 2 shows the relative density of the slate erratics, each dot representing many erratics. The slate is present in all sizes from pebbles to blocks three feet long. Many of the pieces are beautifully striated on one or more sides, but they are mainly rectangular, and show very little

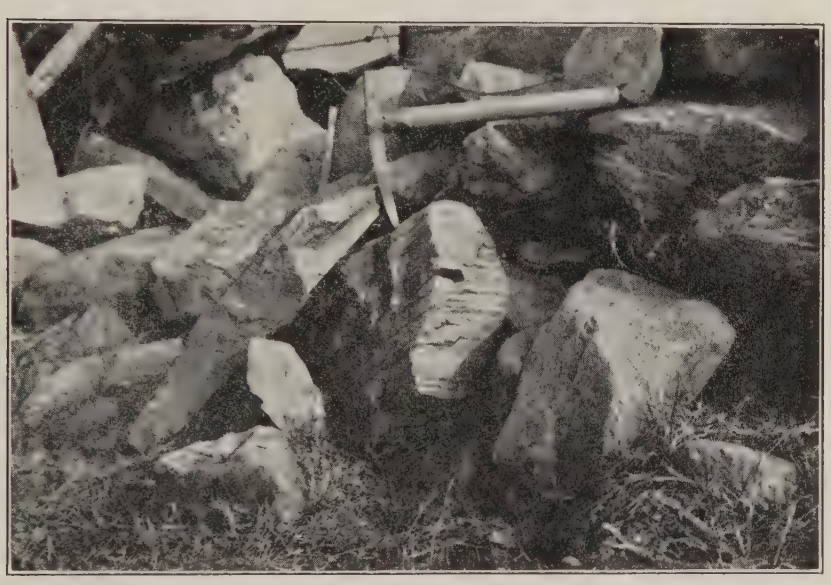

Fig. 4. Varved slate and igneous erratics in pile at edge of field, southwest Section 20, Blooming Grove Township.

rounding. In this area the slate is so common that it has been used for flagstone walks and for a few walls.

The slate is banded, with alternating black and light gray, straight, even bands (Fig. 4). The light bands are the coarser, in a few specimens being almost a fine grained quartzite, indicating that the original material was silt, and not clay. The thickness of the light bands in various pieces varies from the thickness of a sheet of paper to a half inch. The dark bands are very fine textured, the thickness varying from a sixteenth to a quarter inch. In some blocks slaty cleavage is well developed, often parallel to the bedding planes.

This slate is believed to have been originally varved clay and silt laid down in Precambrian glacial lakes, probably upon till which later became tillite. The coarse, thicker layers were laid down in the summer (Antevs, pp. 1–6): the darker, finer, thinner layers in the winter. After deposition, the ancient glacial material was compacted and metamorphosed. Such banded slate, in close relationship to tillite, is known to outcrop in Ontario and Quebec (Coleman, p. 234).

SOURCE

All igneous and metamorphic erratics in Ohio must necessarily have been brought from Canada by the Wisconsin or earlier ice sheets. The main area of Cobalt tillite lies in Ontario (Coleman, p. 225) too far west to be the point of origin for the boulders in Richland County, but the small area of Cobalt series at Lake Chibougamau in Quebec (Coleman, pp. 224–225), which lies approximately northeast of Richland County, is not an impossible source for these boulders. As Coleman points out, the centers of the "Labrador" ice sheet were in northern Quebec, east of James Bay (Coleman, pp. 16, 17, map p. 22). The farthest east outcrop of Huronian tillite is east of a line drawn from "Labradorean" centers 2 and 3 (Coleman, map p. 22). Therefore the tillite boulders in Ohio could have come from known Canadian outcrops. Since varved slates are associated with many known tillite outcrops it is quite likely that the tillite and varved slate erratics were brought to Ohio from the same Canadian locality.

The writer wishes to point out only a possibility that the erratics herein described are from Cobalt rocks, not to press the probability of such an origin.

No explanation of unusual concentrations of erratics in restricted localities is entirely satisfactory. Some concentrations may be due to the breaking up in the last part of the transportation process of a single huge erratic. Wolford (pp. 362–367) describes an erratic containing 225,000 cubic feet of limestone in the Illinoian till near Oregonia, Warren County, which was carried at least several miles. If this huge erratic had been carried farther it might have broken into smaller pieces, thus giving a concentration of smaller limestone erratics at some locality. Large limestone erratics in Columbiana County are described as transported from another county (Stout and Lamborn, p. 47). The Niagaran limestone erratics

concentrated in a small area in southeastern Morrow County, shown the writer by Professor Lord, may be parts of a single huge erratic which was broken up not far away. That the concentration of slate erratics in northern Richland County may be due to the breaking up of a single huge slate erratic, not far north of the present slate location, is an hypothesis that must be considered.

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For the Plant Physiology Laboratory

This book is similar to the first half of the same authors' *Methods in Plant Physiology.* The material of the earlier book has been slightly condensed and in part revised, in order to adapt it to the laboratory part of elementary or intermediate courses in plant physiology. The 167 experiments described are mostly well selected and well planned. The book will be useful both as a laboratory text and as a reference for teachers of plant physiology, general botany and biology.—*B. S. Meyer.*

Experiments in Plant Physiology, by W. E. Loomis and C. A. Shull. 213 pp. New York, The McGraw-Hill Book Co., 1939.

Lifebelts

Readers of Eric Temple Bell's previous books will need no introduction to his pungent stimulating style. In typical Bell manner, he examines in this book the various devices in which man has from time to time lodged his faith. Acting as "neither judge nor jury," but merely as a guide," Dr. Bell with penetrating insight takes up in turn erstwhile life-belts, including, among others, religion, government, righteousness and justice (twin life-belts of the middle ages), internationalism, and science. Needless to say, the discussion is clear, witty and altogether intriguing.
L. H. S.

Man and His Lifebelts, by Eric T. Bell. viii+340 pp. Baltimore, The Williams and Wilkins Co., 1938. $3.00.

Medicine in Many Languages

This book should be the answer to the prayers of many physicians, public health officers and nurses. It contains a carefully selected list of medical words in English, followed by their translations into German, French, Italian and Spanish. The vocabulary is extensive, and appears to be fairly complete from the medical and social workers' standpoint. Following the vocabulary there is presented a series of medical phrases, with translations, in the form of questions, requests and commands which will be found useful in bedside technic and in army medical work.—*L. H. S.*

Medical Vocabulary: English, German, French, Italian, Spanish, by Joseph S. F. Marie. ix+358 pp. Philadelphia, P. Blakiston's Son and Co., 1939.

FIVE NEW GENERIC NAMES IN THE CHALCIDOIDEA (AUSTRALIA)

A. A. GIRAULT

While completing a systematic Monograph of the Australian Chalcidoidea, the following new genera have been discovered. I take the opportunity also to propose a few new names of species. The group is Hexapoda Hymenoptera.

Leptospermophila new genus

Sphegigasterine Pteromalidae. Like *Parapterosemoidea* Girault but the antennae with two ring-joints, the parapsidal furrows not complete (extending a half way from cephalad), the propodeum bears a distinct neck, a long complete lateral carina, a foveate sulcus from the minute, round spiracle and a median carina which forks a half way down from the base of the part, each fork proceeding to the lateral carina near apex. Marginal vein shorter, slightly exceeding the elongate stigmal, slightly shorter than the postmarginal. Segment No. 2 of the abdomen somewhat exceeding the third segment, combined the two occupying half of the surface of the abdomen. Scrobes united, forming an obtuse, parallel-sided channel to the median ocellus. Lower face deeply incised just laterad of the clypeus, the latter very wide, composed of two wide lobes separated by a median notch and each lobe with a median emargination. Petiole somewhat longer than wide.

Leptospermophila fauna new species. Genotype.

Aeneus, the wings clear. Scape, petiole, knees, tibiae and tarsi yellow, the venation darker. Pedicel short but exceeding the first funicle segment which is square, the rest of the funicle segments widening distad, the last of them distinctly wider than long. Flagellum yellowish. Sculpture usual. A female specimen collected by Henry Hacker from the flowers of *Leptospermum flavescens*, Oxley, Queensland, September 24, 1916.

Magellanana new name

For *Blatticidella* Girault, 1923, October, preoccupied by *Blatticidella* Gahan and Fagan, 1923 (March; or according to Zool. Record, April).

Magellanana aereitibiae (Girault). Named for the explorer Magellan. Encyrtidae.

Grantanna new name

For *Neocentrobia* Blood (1925, Ann. Rep. Proc. Bristol Nat. Hist. Soc., (4), 5: 254) not *Neocentrobia* Girault, 1912. Named for Gen. U. S. Grant. Trichogrammatidae.

Coccidoxenus magellani new name.

For *Coccidoxenus* (*Tetracnemella*) *australiensis* Girault, Memoirs Queensland Mus., 1915, 4: 170. Preoccupied by *Coccidoxenus australiensis* (Girault).

Pleistodontes mayri new name.

For *Pleistodontes froggatti* Grandi, 1916, Boll. Lab d'Zool. gen. e agrar. d'scu. Sup. d'Agric., Portici, 11: 150–159 not *P. froggatti* Mayr years earlier.

Chalcis aurea Girault new species, Mem. Queensland Mus., 4:321, 1915.

Dimeromicrus breviventris Girault new species, idem, 4: 277.

Lincolnanna new genus, family **Pteromalidae**

In my modernized table of genera, this species runs to *Apterosemoidella* but segment No. 2 of the abdomen occupies a bit over a fourth of the surface and distinctly exceeds the next three segments which are subequal and a bit over a half the length of No. 2 taken together. Furrows narrow, fine, curved lines. Clypeus bidentate, the teeth obtuse. Propodeum with a rather short neck, straight lateral carinae and a straight, rather narrow spiracular sulcus (nearly parallel with the lateral carina but not very close to it). There is a tooth-like projection centrally between the sulcus and the lateral margin. Petiole distinctly longer than wide. Sutures of the club faint, no nipple. Third ring-joint equal to the other two, larger than usual. Palpi 3- and 4-segmented. (A second tibial spur, very small and stout is indicated but doubted).

Lincolnanna malpighii nov. Genotype.

Small. Dark aeneus, the wings clear; legs (except the washed aeneus coxae) and the scape yellow. First funicle segment square, shorter than the pedicel, the others slightly smaller in succession. Scaly reticulate. Palpi dark except the pale distal joint (at least in outer pair), all joints of the outer longer than wide, No. 4 longest, No. 3 shortest and a half longer than wide. Middle femora with a stout, dark bristle near apex ventro-laterad.

Postmarginal vein elongate, subequal to the marginal, nearly twice longer than the long, slender stigmal, the latter slightly curved. Venation yellow, the stigmal knob black. Discal ciliation extending to the base of the marginal vein, nearly the cephalic half of its basal margin deeply bayed; a short, oblique line of larger cilia extends from the base of the bend of the submarginal vein (the basal nerve); and a loose pair of lines of still larger cilia (and more slender) extends under and along the marginal vein and amongst the other cilia of the regular discal ciliation.

Later, the wing was examined again in reference to the basal nerve just coming into notice; it is ciliated by 4–5 minute cilia (yet these are larger than the cilia of the main ciliation); and the vein is remote from both the main ciliation and the cubital nerve.

A female taken at Gympie, Queensland. Named for Abraham Lincoln.

Australochalcis new genus, family **Chalcididae**

From *Chalcis*. Hind tibiae short, swollen distad, attaining only to the first femoral tooth. Scutellum flat, unarmed at apex. *Male.*

Australochalcis humilicrus nov. Genotype.

Black, the wings hyaline, their veins black. Red: Hind coxa, hind femur. Golden: Tegulae, first and second knees and the tarsi. There is also a small gold oval its own length from base, upon the hind tibia. This, of course, dorsad. Second segment of the abdomen equal to half of the surface. Hind femur with nine unequal teeth, all small. Funicle segments square, exceeding the pedicel.

More details are reserved for the Monograph noted. (MSS. now in Queensland Museum.)

A male taken at Chinchilla, Queensland, Nov., 1929. A. P. Dodd.

In accordance with the best possible practice, I have changed the name of the fourth genotype above because its first name was abominably long, having eight syllables. Nomenclature needs every possible assistance to simplify it, more especially in the needed provision of up-to-date lists of generic names.

German for the Scientist

The author of this dictionary, through his association with students who were acquiring a reading knowledge of German, and with research workers who were attempting to put such knowledge to practical use, has realized that modern scientific research presents complicated interdepartmental problems. Hence any scientist needs a dictionary covering not only his own special field but many related fields as well. Dr. De Vries has attempted to prepare such a German-English science dictionary. In compiling it, he had the able assistance of many outstanding men of the science faculty of the Iowa State College. The result is "the first dictionary of its kind." It appears to be well suited to its purpose, and should be a boon to the graduate student and the researcher alike. There are 48,000 entries.

L. H. S.

German-English Science Dictionary for Students in the Agricultural, Biological and Physical Sciences, by Louis De Vries. x+473 pp. New York, The McGraw-Hill Book Co., 1939. $3.00.

Science Down the Ages

"Thought about the nature of the external world begins with magic, develops into religion, next reaches the level of philosophical speculation, and finally attains the scientific method." This passage from the early part of the book sets forth concisely the general plan of this history of science. From earliest times down to the present the thread of the development of science is traced. It is remarkable how much material has been packed into the short space of this essay, and it is gratifying to find that the style is delightfully readable. Student and layman alike will enjoy this account of the development of science and the methods of science.

L. H. S.

The March of Mind, by F. Sherwood Taylor. xiv+320 pp. New York, The Macmillan Co., 1939. $3.00.

THE NATURE OF THE EVOLUTION OF FUNDAMENTAL POTENTIALITIES IN THE PLANT KINGDOM[1]

JOHN H. SCHAFFNER

When one studies the plant kingdom in all of its more important aspects, he becomes aware of the fact that he is dealing with a remarkably consistent system, extending from very simple units on the lowest level to aggregates of exceedingly complex units on the highest level. The most remarkable facts in evidence are that the fundamental potentialities are added step by step as one follows up the ascending scale of complexity, that when once added these fundamental potentialities are not lost but are carried up to the highest levels of the plant series, and that therefore the plants of any general stage or subkingdom all possess a complement of similar fundamental potentialities. The plants of any subkingdom contain the complete complement of fundamental potentialities acquired in the forward evolution of the whole series to the given level.

From a practical and theoretical survey of the plant kingdom it becomes clearly evident that we can recognize ten progressive stages or subkingdoms. These stages are quite distinct and easily delimited from each other. Seven of them are represented by living forms and three are either theoretical or represented only by fossils. There are seven subkingdoms of living plants, no more and no less. One hundred general potentialities, represented by important structures or activities, have been segregated and listed below for the entire plant series. They are the potentialities which are most in evidence from the general viewpoint. Others could be listed, but they would not necessarily assist in making clearer the fundamental facts and principles involved.

The mechanisms in which these fundamental potentialities are contained are in the protoplast, but are not to be confused with genosomes having the potentialities for the genes of Mendelian heredity. In most cases the mechanisms may be conceived of as being complex systems of autogens scattered throughout the entire protoplast or a large part of it. Where in the protoplast, for example, is the mechanism causing the

[1]Papers from the Department of Botany, The Ohio State University, No. 411.

process of respiration? What is the nature of the protoplasmic pattern which determines the character and sequence of the twelve fundamental stages in the typical antithetic alternation of generations life cycle characteristic of all higher plants from the liverworts on up? What kind of a grouping of genosomes would determine that in the Bryophytes and Homosporous Pteridophytes the sexual state is always normally determined in the gametophyte, the sporophyte being a neutral generation, while when one passes up to the middle level of the Pteridophytes he finds that the sexual state is always determined in some stage of the sporophyte ontogeny throughout all the phyletic lines up to the highest seed plants? For such questions our present-day genetics has no answers. In fact, our present-day genetics is but a superficial discipline. These fundamental processes and characteristics are a part of the universal heredity of the plant much more important in the study of the general evolution and taxonomy of plants than all the superficial Mendelian genes, so far discovered, combined. For the present we may then simply assume that the protoplasmic mechanisms responsible for the fundamental potentialities are complex patterns of autosomes pervading in most cases at least the entire protoplast, although some may be confined to the nucleus only.

The ten subkingdoms are given below in connection with the one hundred fundamental potentialities. The fact of a definite, progressive, accumulative process in the evolution of the plant kingdom was presented in a general but incomplete way in two earlier papers. See "Principles of Plant Taxonomy, X" (Ohio Jour. Sci. 31: 77–96, 1931) and "Phylogenetic Taxonomy of Plants" (Quart. Rev. Biol. 9: 129–160, 1934).

ONE HUNDRED PROGRESSIVELY ACCUMULATED FUNDAMENTAL POTENTIALITIES EVOLVED IN THE PLANT SERIES, ARCHEOPHYTA TO ANGIOSPERMAE

In the progressive evolution of the plant kingdom, the fundamental potentialities acquired or changed to a more advanced condition are apparently never lost and very rarely inhibited in any group of organisms.

I. ARCHEOPHYTA. Biont stage; theoretical. The first five potentialities listed below are attributes of all plant and animal organisms.

1. With the genesis of living things or bionts there came into existence autogens possessing the power of assimilation or self-perpetuation. These autogens may be conceived of as definite patterns or

systems of molecules forming colloidal particles and having the power to duplicate themselves in their own field from the surrounding atoms, ions, and molecules.

2. The potentiality of self-division of the autogens with the two daughter particles retaining all the potentialities of the mother autogen.

3. The power of mutation, through which from time to time an individual autogen is changed to a new pattern with new potentialities.

4. Autogens of two or more kinds with the power of correlative interaction and a number of these ultimate living units held together in a unitary reaction field.

5. Nutrition, holotrophic but without chlorophyll. This condition was soon advanced to the chloro-holophytic condition and from either level there arose parasitic and saprophytic bionts and organisms, and in the animal series eating organisms.

II. PROTOPHYTA. Organisms with protoplasts. Beginning of the problem of cell organization and evolution of multicellular, complicated living mechanisms.

6. The simplest unicellular condition consisting of a definitely organized reaction system or protoplast. Practically all organisms up to the highest plants and animals exist as separate cells in one or more stages of their life cycle. The cells in the first evolutionary stage have either no definitely organized nucleus or a nucleus without either nuclear membrane or definite chromosomes and without a typical karyokinesis.

7. The potentialities for the simpler physiological processes of the cell, as absorption, mobility of the protoplasm, irritability, etc.

8. Respiration, which is a fundamentally important process taking place in the active cells of all plants and animals.

9. Division of the cell as a whole, with perpetuation of like structures and potentialities in the daughter cells, alternating with resting periods.

10. Development of a cell wall, with cellulose or other chemical compounds.

11. Development of alternate phases of walled cells and naked cells in the life cycle, rarely lost in any plants except in a few of the Thallophyta.

12. The evolution of a more complex system of the protoplasm with highly organized nucleus, with nuclear membrane, chromosomes, nucleolus, etc.

13. Development of a definite chloroplast with chlorophyll.

14. With the potentiality for chlorophyll production, came also the process of photosynthesis with the usual formation of sugar, starch, etc. This process and the production of chlorophyll are sometimes partly or completely lost by the evolution of inhibitory factors.

15. With the evolution of a more perfectly organized nucleus and chromosomes, the typical karyokinesis and resting stage of the higher plants and animals was initiated.

16. Definite organization of the chromosomes and their equational division.

17. A special system for the separation of the daughter chromosomes, including spindle fibers, centrosomes, a definite polar organization, and polar radiations at each karyokinesis.

18. Evolution of a flagellate or ciliate motor system, present in at least one phase of the life cycle, in the main line of the plant series and apparently never lost until the stage of the more advanced seed plants. The ciliate condition was developed in some series at a very low evolutionary level as in bacteria, and on the other hand, there is no evidence apparently that it was ever developed in such lines as diatoms, conjugates and red algae.

III. NEMATOPHITA. Beginning of plants with sexuality.

19. Potentiality of sexuality with appearance of primary sexual states giving the property of attraction and fusion between isogamous gametes, the cells from time to time being in any of the three states—female, male, neuter.

20. The reduction division phase with synapsis of chromosomes. The sequences of fertilization, reduction, and the individual give rise to various types of life cycles.

21. Mendelian heredity as a result of fertilization and meiosis and exhibition of dominance and recessiveness in the diploid phase.

22. Multicellular condition, at first colonial, and with a restriction of separation of cells; in the main series developing a linear aggregate. In the highest plants the filament disappears or may be said to be restricted to the first two cells.

23. Attainment of heterogamy, through earlier determination in the cells of the sexual state.

24. Normal, higher type of heterogeny with extremely dimorphic gametes.

25. Correlative interaction of cells in the multicellular organism.

26. Differentiation system depending on physiological gradients in the multicellular body and a complexity of major and minor hereditary potentialities, not all of which are expressed at a given time or in a given cell.

27. Establishment of definite vegetative and reproductive phases in the process of differentiation, following a regular sequence in the usual ontogenetic cycle of the multicellular, differentiated plant body.

28. Development of base and apex of the filament and in the higher forms a base and apex in the growth of the solid aggregate individual.

29. Evolution of definite spermaries and ovaries and retention of the egg in the ovary.

30. Secondary sexual states in at least some of the body cells of the gametophyte causing secondary sexual dimorphism, through influencing hereditary expression, but not producing attractive properties as the primary states do in the gametes.

IV. PROTO-BRYOPHYTA. The great transition hiatus leading to the Metathallophyta. There are no known living or fossil plants which represent this evolutionary level.

31. Progression from a linear aggregate to mature solid aggregate, the filamentous condition being confined to the juvenile phase of the

gametophyte. The solid buds produce a dorsiventral or bilateral gametophyte in the main series which in some lines advance more or less to a radial symmetry again.

32. Evolution of an epidermis and distinct internal tissues in the gametophyte or sporophyte or in both.

33. Evolution of rhizoids on the gametophyte. The rhizoids disappear in the higher plants through the great reduction of the gametophyte.

34. Typical antithetic alternation of generations life cycle established with the twelve antithetic stages.

35. Gametangia organized into definite types of archegonia and antheridia, which undergo progressive reduction in the higher groups of plants.

V. BRYOPHYTA. The lower homosporous Meta-thallophyta.

36. Completely parasitic, enclosed, one-phased sporophyte.

37. Radially symmetrical condition of the sporophyte.

38. Two-phased sporophyte, the juvenile enclosed and the mature exposed condition.

39. Development of the ability for dehiscence of the sporangium. This is never lost in the main series except in the megasporangium of seed plants.

40. General fundamental potentiality complex through which the sporophyte develops four general regions or systems—(1) an absorption system, (2) a supporting and conducting system, (3) a photosynthetic system, and (4) a spore-reproductive system.

41. Transpiration established in the sporophyte, with stomata. This system is very rarely lost.

42. Potentiality for a very definite type of stomata, the general type continuing to the highest plants.

43. Development of lateral expansions or outgrowths in some of the highest mosses, as the hypophyses of Splachnums.

44. Evolution of a central strand in the sporophyte, shown in the higher plants as the embryonic plerome, as distinguished from the periblem or cortical tissue.

45. First stage, in the evolution, of the shifting of spore reproduction from the central axis to the periphery, by the development of a central columella in the sporangium of the higher Bryophytes.

VI. PROTO-PTERIDOPHYTA. Large transition hiatus leading to the homosporous vascular plants.

46. Two-phased sporophyte with parasitic and completely independent phases, the enclosed and exposed conditions still present in the parasitic phase, as in the Bryophytes.

47. Sinking of the archegonium venter into the tissues of the gametophyte. The horned liverworts of the Bryophyta also have sunken archegonium venters.

48. Potentiality for long-continued growth of the sporophyte.

49. Complete evolution of indeterminate growth of the sporophyte, the reproduction process not followed by immediate death. In the

higher plants this potentiality may be inhibited by the introduction of the annual habit.

50. Negative geotropism of the stem bud.

VII. PTERIDOPHYTA HOMOSPORAE. Completely evolved vascular plants with a two phased sporophyte and an indeterminate axis.

51. The normal vascular system, appearing in all the lines of higher plants, in the main evolutionary line with pith on the inside and cortex on the outside.

52. Highly evolved cambium system with secondary growth in thickness, in the main series. This potentiality is, however, reduced or lost in various phyletic lines but not in the main ones.

53. Potentiality for the production of typical leaves with a vascular supply.

54. Fundamental potentiality for the spiral development of the leaves in the sporophyte. This spiral growth reaction is present with various modifications in all living vascular plants, and apparently in some fossil Proto-Pteridophyta.

55. The complete centrifugal shifting of the reproductive process from the stem tip and central axis to the leaves.

56. Roots, originating at first as lateral organs and later as basal organs of the embryo.

57. Geotropism of roots.

58. Decided dorsiventrality of the leaves usually with phototropism.

59. Branching potentiality evolved which is normally monopodial in all living lines except in the Lepidophyta in which it is dichotomous and was apparently introduced in a very early Proto-Pteridophyte stage.

60. Dimorphism between sporophylls and foliage leaves attained on the higher levels.

VIII. PTERIDOPHYTA HETEROSPORAE. Attainment of the level in which sex determination takes place in the sporophyte.

61. Shifting of time of sex determination from the gametophyte to the sporophyte.

62. In consequence of shifting of time of sex determination both secondary male and female states developed in some part of the sporophyte, on the lowest level in the same sorus of a leaf.

63. In consequence of secondary sexual states in the sporophyte, dimorphic sporangia, sporocytes, and spores produced, microspores and megaspores.

64. Unisexual gametophytes, having their sex completely established in the spore before germination. The establishment of secondary sexual states before the time of the reduction division determines that there is no segregation of sex through the separation of the synaptic chromosomes but all the spores and the subsequent gametophytes coming from one sporocyte continue the sexual state previously established in the sporangium and sporocyte. Sex-reversal in heterosporous gametophytes is very rare.

65. Decided reduction in size of gametophytes, namely more prompt determination of cell lineage.

66. Very extreme dimorphism of the male and female gametophytes.

67. Earlier sex determination in the ontogeny, each sorus having but one secondary state developed.

68. Advance in time of sex determination to the incept of the sporophyll, resulting in dimorphism of sporophylls, megasporophylls and microsporophylls.

69. Decided reduction of the antheridium to a single unit in the male gametophyte.

70. Complete or nearly complete inhibition of chlorophyll development in the gametophytes which are dependent on the parent sporophyte through the food stored in the spores.

IX. GYMNOSPERMAE. Attainment of the seed habit, with parasitic gametophytes.

71. Retention of megaspores and microspores, with germination in the sporangia.

72. In consequence of spore retention, parasitic gametophytes.

73. Pollination process established.

74. Acquisition of a two-phased male gametophyte with development of the parasitic pollen tube in the ovule.

75. Ovules or megasporangia with integuments.

76. Resting stage of embryo intercalated between the parasitic and independent phases of the sporophyte, resulting in seed dormancy.

77. Abscission of fruit or seed.

78. Food storage, during development of the seed, in the embryo sporophyte or surrounding parasitic tissues or in both, which enables the embryo to become established as an independent plant in the process of sprouting.

79. Sprouting of the seed or renewal of growth activity in the sporophyte embryo, with complex reactions developed at this phase, not only an awakening from dormancy but various other activities, as the definite reaction to gravity, etc.

80. Increase in functional axillary bud development to a greater or less degree, giving rise, on the higher levels, to much branched systems, which may be simplified again in various higher series through a counter-evolutionary movement, as shortening the ontogeny to the annual condition, etc.

81. Determinate reproductive axis of the sporophyte, or flower potentiality, in all the higher series. The lowest fossil Gymnosperms are without flowers and a few living species still have indeterminate reproductive axes, while many of the Pteridophytes have flowers.

82. Extreme differentiation of tissues of carpel and stamen from leaf tissue, the carpels and other parts modified with them finally giving rise to the fruit.

83. Evolution of a standard type of embryo with radicle, plumule, and cotyledons.

84. Development of a peduncle below the flower, on the higher levels in various lines. This may be reduced again. Peduncles are also developed in some Pteridophytes.

85. Development of internodes in most of the higher series. These may be reduced again through new evolutionary movements. Some of

the lower groups, even of Homosporous Pteridophytes also have the internodal potentiality.

X. ANGIOSPERMAE. The extreme stage of complexity of fundamental potentialities, with closed carpels, stigmas and endosperm developing from a triploid or polypoid fusion nucleus.

86. Development of special complex types of xylem vessels in the vascular bundles.

87. Closing of the carpellate leaf, producing an ovulary.

88. Development of a stigma.

89. Potentiality for a very consistent type of microsporophyll, or stamen, normally with a filament and an anther with four microsporangia which are rarely reduced to two.

90. Very decided limitation of the growth of the gametophytes to an eight-celled female and a three-celled male condition, as the usual type in most groups.

91. In nearly all cases a three-celled egg-apparatus, which apparently represents a vestigial archegonium.

92. Development of the pollen tube through the stigma, style, open cavity of the ovulary, and the micropyle. This condition sometimes modified by the introduction of chalazogamy.

93. Evolution of nonciliated spermatozoids. This condition is also attained in the higher phylum of the Gymnosperms, the Strobilophyta.

94. Triple or multiple fusions within the female gametophyte resulting in a primary endosperm nucleus in addition to the diploid oospore.

95. Triploid or occasionally polyploid endosperm or xeniophyte.

96. Potentiality for a definite gradient in the bisporangiate flowers, causing male expression first, and followed by a sex-reversal to female expression. This is modified in many lines by the progression in the time of sex-determination to moneciousness and dieciousness, but commonly with vestigial development of the opposite set of sporophylls.

97. Potentiality for the development of a perianth which is rarely completely lost through the progressive evolution of the determinateness of the flower. There is a slight development of the perianth in some groups of Pteridophytes and Gymnosperms.

98. Differentiation of the perianth into a distinct calyx and corolla, except in some of the lowest types and some of the advanced, reduced types of flowers.

99. Evolution of an inflorescence in all but the lowest types. This is occasionally reduced again to a solitary flower in some of the advanced lines.

100. Union of the carpels into a gynecium with a compound ovulary in all except the lowest members of the various phylogenetic series. The ovulary is usually plurilocular in the lower levels and unilocular in the higher levels.

One may wonder as to what is the fundamental cause of this remarkably consistent, progressive accumulation of fundamental modes of reaction. Whatever the cause, this accumu-

lative, irreversible series gives a definite picture of the primary evolutionary process. It shows that evolution in its fundamental aspects is an intrinsic and definitely kinetic process and that there is a principle of stability involved as well as a principle of change. It also shows that the plant kingdom as a whole is a direct contradiction of the old teleological hypotheses of evolution as contained in Buffon's direct response to environment, Lamarck's use and disuse, and Darwin's natural selection. It also is plainly a contradiction of some of the newer genetic hypotheses which attribute the primary cause of evolutionary action to the effect of various kinds of radiations on the cell, such as cosmic rays, violet rays, X-rays, etc. These universal physical agents have been active during the geological ages and must have hit every susceptible particle of protoplasm of all plants myriads of times, and if they were primary causal agents we should either have a plant kingdom of a single species or a haphazard, anarchistic taxonomic system; which is a direct contradiction of the actual evolution which has taken place.

When one has ascertained the fundamental potentialities for each subkingdom, one may proceed to catalog all the potentialities or characteristics contained in each phylum or class or other group in addition to the accumulation common to the entire subkingdom in which the phylum or class has its basis. This has not been attempted, but to illustrate the way the method can be used in determining the evolutionary level to which any species has attained a list of the total potentialities or characteristics possessed by the species may be made. Some of these potentialities may be simple Mendelian genes. The writer has attempted to catalog thirty-four species in this manner, a summary of which is presented in the chart given below. Eight of these summations are here presented to illustrate the progression of complexity from the lowest to the highest level.

No claim is made that these summations are complete, for a complete summation will require an enormous amount of study of each species. However, an attempt has been made to study the different species on the same general basis and thus the series of numbers for the eight examples given—16, 42, 68, 95, 122, 140, 170, 200—does clearly indicate each species' position in the taxonomic scale. A similar method can be used to determine the relative position of the genera or species in a group in relation to each other if they are to be arranged in the order of their evolutionary complexity as higher or lower types.

Nitrosococcus nitrosus Mig.

This is an autotrophic bacterium belonging to the Coccaceae and represents the lowest type of organism. This autophyte was isolated from the soil of Quito, Ecuador, South America, by Winogradsky.

Phylum, Schizophyta; class, Schizomycetae; order, Bacteriales; family, Coccaceae.

I. The first ten of the one hundred enumerated potentialities of the general accumulative list.

II. The special potentialities accumulated in the species.

11. The specific type of autrophic reaction deriving energy through oxidizing ammonia to nitrite and obtaining carbon from the atmospheric carbon dioxide.

12. The spherical or coccus shape, which is the simplest shape of a bit of colloidal protoplasm surrounded by a wall.

13. Specific size of the rather large cells, with a diameter of 1.4–1.7 microns.

14. Non-motile condition—no motile stage known. The absence of cilia represents the simplest, most primitive condition of the living cell.

15. Apparent absence of a zooglea stage, always growing as free cells without special pigment formation. This represents the simplest cellular condition imaginable.

16. Potentiality for a special physiological condition—an obligate aerobe.

The first ten conditions are fundamental potentialities common to all higher organisms. In the higher, however, there is a definite nucleus with a more complex structure. *Nitroscoccus nitrosus* has apparently only six special characteristics, and even of these two appear quite generally in the life cycle of higher organisms, namely the spherical, free cell condition and the non-motile condition.

Sphaerella lacustris (Girod.) Wittr.

This active unicellular alga is often abundant in rain water pools and often colors these a bright red because of the development of haematochrome in its cells.

Phylum, Gonidiophyta; class, Chlorococceae; order Volvocales; family, Chlamydomonadaceae.

I. The first twenty-one of the one hundred general potentialities.

II. The accumulation of special potentialities in the species.

22. Potentiality giving motile and no-motile vegetative cells in the ontogeny.

23. Flagella developed in the motile stage or zoospores.

24. The definite biciliate condition of the zoospores and gametes.

25. Centrosomes present, the dynamic centers of the flagella, spindle poles, and polar radiations.

26. An eye spot in the active cells.

27. Spherical shape of the resting cells.

28. Oblong-ovoid shape of the gametes.

29. The resting zygote.
30. Cuticularized wall of the zygote.
31. Potentiality for the red coloring matter or haematochrome.
32. Pointed ciliate end of the zoospores with two minute openings in the cellulose wall.
33. Peculiar, loose cell wall of the zoospore with protoplasmic strands passing to the protoplast within.
34. Characteristic size of the cells of the species.
35. Characteristic size and shape of the bell-shaped chloroplast.
36. A pyrenoid in the chloroplast.
37. Long resting stage or dormancy under dry conditions without loss of vitality.
38. Gelatinous pectose in the cellulose wall.
39. Power of dissolving the cell wall at certain points.
40. Definite reaction to light.
41. Characteristic swarming of the gametes in the water.
42. Diploid number of chromosomes in the zygote, with the reduction division during its germination.

Riccia fluitans L.

This species is a simple liverwort growing in the water or on wet banks.

Phylum, Bryophyta; class, Hepaticae; order, Marchantiales; family, Ricciaceae.

I. The first thirty-eight potentialities of the general series.

II. The special potentialities accumulated in *Riccia*.

39. Potentiality determining the slender thalloid form of the gametophyte.
40. Gametophyte conditioned to live in fresh water.
41. Dichotomous branching.
42. Adventive branches from ventral sides of the thallus in the floating form.
43. Several distinct tissue layers in the thallus.
44. Thallus with a median furrow.
45. Development of large air cavities.
46. Dorsal epidermis of thallus.
47. Small openings in the epidermis to the air chambers in the terrestrial form.
48. Ventral scales in a row.
49. Double row formed by rupturing of the ventral scales.
50. Characteristic form of the scales.
51. Rhizoids with a smooth inner surface.
52. Tuberculate rhizoids.
53. Violet color of the ventral scales and the margins of the thallus.
54. Hermaphroditic condition of gametophyte.
55. Characteristic antheridia.
56. Archegonia with stalk, venter, neck, and lid cells.
57. Special division of the egg mother cell to form the egg and ventral canal cell.

58. Spherical form of the egg.
59. Dissolving of the neck canal cells and the ventral canal cell.
60. Opening of the lid cells of the neck.
61. Antheridia and archegonia immersed singly in cavities of the dorsal surface, scattered in the thallus.
62. Prominent antheridial ostiole.
63. Biciliate spermatozoids which swim down the necks of the archegonia.
64. Spherical sporophyte in the venter.
65. Ventral protuberance of the thallus, produced by the growth of the sporophyte.
66. Complete transformation of the inside of the sporophyte into sporocytes and spores.
67. Characteristic, large spores with aerolate surface.
68. Disappearing of the epidermal wall of the sporophyte (sporangium) at the maturing of the spores.

Ophioglossum vulgatum L.

The adder-tongue fern represents about the simplest condition of the living vascular plants, at least of those belonging to the Ptenophyta.

Phylum, Ptenophyta; class, Phyllopteridae; order, Ophioglossales; family, Ophioglossaceae.

I. The first fifty-nine fundamental potentialities of the general series.

II. Accumulation of potentialities in the *Ophioglossum* series.

60. A short, nearly erect, slow-growing retreating rhizome.
61. Character of the cortex of the rhizome.
62. Distinctive type of vascular bundles with characteristic wood cells.
63. Characteristic shape of foliage leaf.
64. General size of leaf.
65. Evolution of petiole.
66. Characteristic type of bud on the rhizome.
67. Potentiality for reticulate or arceolate venation.
68. Several vascular bundles in base of leaf.
69. Erect vernation of leaves.
70. Distribution of stomata.
71. Succulent texture of plant.
72. Slender fleshy roots, occasionally with dichotomous branching.
73. Specific structure of the roots.
74. Sporophyll with distinct sporangiophore on upper side.
75. Long stalk of sporangiophore.
76. Characteristic round sporangia.
77. Sporangia in two rows on sporangiophore.
78. Characteristic dehiscence of bivalved sporangia.
79. Characteristic shape and size of spores.
80. Yellow color of spores.
81. Germination of spores to form a small characteristic protonema.
82. Potentiality for subterranean growth of gametophyte.
83. Bean-shaped character of gametophyte.

84. Thick, fleshy texture of gametophyte.
85. Potentiality inhibiting the development of chlorophyll in gametophyte.
86. Mycorrhizal relation with a fungus, giving phagophytic nutrition.
87. Character of the rhizoids on gametophyte.
88. Hermaphroditic condition of gametophyte.
89. Short neck of archegonium.
90. Lid cells of archegonium.
91. Division of mother cell into the egg and ventral canal cell.
92. Neck canal cells and ventral canal cells dissolving.
93. Characteristic antheridia.
94. Large, spirally coiled, multiciliate spermatozoids.
95. Characteristic bryophyte type of embryo development, the inner of the first two cells of the embryo giving rise to the foot and the outer one to the first leaf, bud and root.

Marsilea quadrifolia L.

The European *Marsilea* is commonly cultivated in greenhouses and botanic gardens and occasionally escapes into favorable habitats. It is the lowest type of the living, leptosporangiate heterosperous ferns.

Phylum, Ptenophyta; class, Hydropteridae; order, Marsileales; family, Marsileaceae.

I. The first seventy fundamental potentialities of the general series, except No. 60.

II. The accumulation of special potentialities in the *Marsilea* line.

70. Highly evolved creeping, rapidly growing rhizome.
71. Potentially fitting the plant for a moist ground of aquatic habitat.
72. Potentiality for internodes between the leaf nodes.
73. Characteristic vascular system with absence of secondary thickening.
74. Characteristic cortex of the rhizome.
75. Sporadic monopodial branching of the rhizome.
76. Characteristic type of roots.
77. Structure of the roots.
78. Reaction to gravity and substratum of the rhizome.
79. Foliage leaf with four leaflets.
80. Long slender petiole.
81. Structure of the petiole.
82. Shape and size of the leaflets.
83. Structure and venation of leaflet.
84. Smooth upper surface of leaflet and slightly hairy lower surface.
85. Distribution of stomata.
86. Reaction to darkness and light, the leaflets folding up like a fan and also nutating with the sun at least in *M. vestita.*
87. Special type of sporophyll, having a special primary dichotomy, the one branch being vegetative, the other reproductive.

88. Usually a single dichotomy of the reproductive branch of the sporophyll.
89. Special length of petiolule bearing the sporocarps.
90. Closing up of the reproductive leaflet and complete fusion of its two valves to form the sporocarp.
91. Yellowish-brown hairs on the petiolules of the sporocarps.
92. Characteristic shape and size of sporocarp, with two teeth at its base.
93. Smooth surface of sporocarp.
94. Hard texture of the mature sporocarp.
95. Internal organization of the sporocarp into eight or nine sori or compartments in each of the two valves.
96. Potentiality for the transformation of the internal tissues of the sporocarp into a gelatinous mass which comes out as a gelatinous cord, bearing the two types of sporangia, when the sporocarp breaks open by two valves in the water.
97. Potentiality which determines the comparative number and distribution of megasporangia and microsporangia in each sorus.
98. Characteristic time of sex-determination in the incipient sporangia.
99. Shape and size of the megasporangium.
100. Cellular structure and shape of the megasporangium.
101. Short thick stalk of the megasporangium.
102. Character of the single surviving megaspore as to shape, size, and surface.
103. Potentiality which causes the destruction of several megaspores during the growth of the surviving megaspore.
104. Character of the abundant supply of starch grains in the megaspore.
105. Spherical shape and small size of the microsporangium.
106. Long slender stalk of the microsporangium.
107. Cellular structure of microsporangium.
108. Abundant number of microspores in a microsporangium.
109. Character of the microspores as to shape, size, and surface.
110. Characteristic development of the female gametophyte in one end of the megaspore.
111. Characteristic opening of the end of the megaspore and the protrusion of the neck of the archegonium.
112. Simple character of the cellular structure of the female thallus.
113. Lack of chlorophyll in the male gametophyte and young female gametophyte.
114. Character of the archegonium with very short neck.
115. Abundant funnel-like mass of gelatinous material coming from the neck of the archegonium into which the spermatozoids swim.
116. Characteristic small male gametophyte developed in the microspore.
117. Cellular structure of the male gametophyte.
118. Very small and reduced antheridium, producing only a few spermatozoids.
119. Bulging out and breaking open of the microspore wall next to the tip of the antheridium through which the spermatozoids escape.

120. Characteristic, large, spirally coiled, multiciliate spermatozoid.
121. Characteristic embryogeny.
122. General character of the young sporophyte with one cotyledon.

Araucaria araucana (Molina) K. Koch.

The Monkey-puzzle-tree represents a primitive conifer type, as indicated by its broad, spirally arranged leaves, its intermittent, rhythmically developed zones of main branches with very coarse ultimate branchlets, and its very primitive type of flowers.

Phylum, Strobilophyta; class, Coniferae; order, Araucariales; family, Araucariaceae.

I. The first eighty-three fundamental potentialities of the general accumulative series.

II. The special potentialities of the *Araucaria* series.

84. Sperms without cilia.
85. Ovules developing without a pollen-chamber.
86. Ovules imbedded in the lower part of the carpel.
87. One ovule for each carpel.
88. Peculiar growth of pollen tube through the carpel tissue.
89. Greater growth of pollen tube as compared with Cycadophyta.
90. Flower production shifted beyond the primary stem axis.
91. Special type of spiral systems in the flowers.
92. Flowers monosporangiate.
93. Diecious condition.
94. Characteristic staminate cone.
95. Leaf-like stamens.
96. Stamens with numerous pollen-sacs.
97. Character of wall of the slender pollen-sac.
98. Characteristic ovoid carpellate cone.
99. Shape and size of carpel.
100. Texture of carpel.
101. Special small ligule on the carpel.
102. Character of ripe carpellate fruit.
103. Characteristic size and shape of pollen-grain.
104. Male gametophyte with numerous vegetative nuclei.
105. Characteristic female gametophyte, originating in a large number of free cells.
106. A number of archegonia in each female gametophyte.
107. Characteristic archegonium with twelve neck cells.
108. Egg and short-lived ventral canal cell.
109. Characteristic embryogeny.
110. Embryo with two cotyledons.
111. Vascular supply of each cotyledon.
112. Seed dry and large.
113. Character of the testa of the seed.
114. Elongated shape of mature seed.
115. Characteristic mode of sprouting.
116. Thickening of the hypocotyl.
117. Type of the spiral arrangement of the leaves.

118. Rhythmical development of zones of branches of the main stem.
119. Meager development of axillary buds.
120. Very robust ultimate twigs.
121. Large broad leaves.
122. Characteristic parallel venation with dichotomy.
123. Smaller leaves in resting zones.
124. Firm thick texture of leaves.
125. Distinctive character of stomata.
126. Abscission of ultimate twigs.
127. Resin passages in the leaves.
128. Highly efficient cambium, producing a large wood cylinder.
129. Wood with uniform tracheids.
130. Tracheids with multiseriate bordered pits, and with spiral thickenings in the primary wood.
131. Characteristic medullary rays one cell in width.
132. Resin produced in the medullary rays and in passages in the roots and bark.
133. Double leaf-traces persistent in the secondary wood.
134. Rather large pith in contrast with other conifer groups.
135. Characteristic outer bark.
136. Cork cambium.
137. Characteristic structure of inner bark.
138. General characteristics of the wood, as strength, fracture, and durability.
139. Development of a tap-root.
140. Branching system of roots.

Magnolia acuminata L. Cucumber Magnolia.

The Magnolia is one of the most primitive types of Dicotyls, although it is probably considerably advanced over the form which must have represented the original ancestral simple tree.

Phylum, Anthophyta; class, Dicotylae; order, Ranales; family, Magnoliaceae.

I. The ninety-eight fundamental potentialities of the general accumulative series.

II. The special potentialities accumulated in the Cucumber Magnolia.
99. Highly evolved woody stem system.
100. Resting vegetative bud.
101. Netted-veined character of leaves.
102. Pinnate venation from a prominent midrib.
103. Dichotomy of the main lateral veins.
104. Characteristic branching habit.
105. Development of a cork cambium.
106. Characteristic type of outer bark.
107. Characteristic inner bark.
108. Rather large pith.
109. Soft texture of pith.
110. Characteristic root system.
111. Branching of roots.

112. Development of root hairs.
113. Reduction of spiralization to a 2–3–5–1 leaf spiral on the vegetative stem.
114. Characteristic length of internodes.
115. Large stipules.
116. Connate condition of stipules.
117. Stipules extending completely around the stem.
118. Silky pubescence on the stipules.
119. Abscission of stipules.
120. Conduplicate folding of leaf in the bud.
121. Characteristic shape of leaf.
122. Characteristic size of leaf.
123. Entire margin of leaf blade.
124. Leaf blade with minute transparent dots.
125. Pubescence on lower side of leaf.
126. Petiole of leaf.
127. Abscission of leaf.
128. Numerous bundle-scars in leaf scar.
129. Characteristic stipular rings on twigs.
130. Bitter aromatic bark.
131. Characteristic, nearly glabrous peduncle of flower.
132. Three-parted perianth.
133. Differentiated calyx and corolla.
134. Double cycle of petals.
135. Characteristic shape and size of sepals.
136. Texture of sepals.
137. Characteristic shape and size of petals.
138. Texture of petals.
139. Greenish-yellow color of petals.
140. Glaucous condition of perianth and gynecium.
141. Deciduous perianth segments.
142. Characteristic shape and size of carpels.
143. Carpels cohering together.
144. Characteristic spiral condition of carpels in gynecium.
145. Shape and size of stamens.
146. Characteristic spiral condition of stamens in andrecium.
147. Color of stamens.
148. Shape of microsporangia.
149. Characteristic shape and size of pollen.
150. Color of pollen-grains.
151. Fragrance of the flowers.
152. Carpels forming follicles.
153. Each carpel with two ovules.
154. Ovules anatropous.
155. Characteristic wall of follicles.
156. Rose color of mature cylindric cone of carpels.
157. Dehiscence of follicles.
158. Fleshy outer seed coat.
159. Red color of seed coat.
160. Bony inner seed coat.

161. Thread-like slender funiculus of seed.
162. Persistence of follicles on the receptacle of the fruit.
163. Fleshy endosperm.
164. Characteristic embryogeny.
165. Very small embryo.
166. Characteristic sprouting of embryo.
167. Wood with distinct heartwood and sapwood.
168. Characteristic medullary rays.
169. Wood diffuse porous.
170. Soft, light character of the wood.

Taraxacum officinale Weber. (*Leontodon taraxacum* L.). Dandelion.

The dandelion is one of the most highly evolved plants and represents the main culmination type in the plant kingdom.

Phylum, Anthophyta; class, Dicotylae; order, Compositales; family, Cichoriaceae.

I. The one hundred general fundamental potentialities.

II. The special potentialities accumulated in the Dandelion series.

101. The change from the more primitive type of stem to the low herbaceous type.
102. The evolution of a typical perennial rosette.
103. Netted-veined leaves.
104. Prominent midvein and weak lateral veins of the pinnately veined leaves.
105. Characteristic angiospermous embryogeny.
106. Two cotyledons.
107. Primitive spiral to cyclic condition of flower.
108. Tetracyclic condition of flower.
109. Syncarpous condition.
110. Advanced determinate condition of the floral axis resulting in epigyny.
111. Change from plurilocular to unilocular ovulary.
112. Single ovule and seed in ovulary.
113. Anatropous ovule from original orthotropous type.
114. Shifting of flowers away from the primary axis to the axillary position.
115. Disk or head evolved, an extremely determinate inflorescence axis.
116. Double condition of involucral bracts around the disk.
117. Characteristic size and shape of the outer bracts.
118. Characteristic size and shape of the inner bracts.
119. Characteristic texture and structure of the bracts.
120. Reflexing of involucral bracts at maturity; two periods, the outer first.
121. Suppression of the leaf bracts subtending the individual flowers.
122. Characteristic white epidermal layer on top of the disk.
123. Very small flowers.
124. Reduction of stigmas to two.
125. Minutely papillose surface of stigmas.

126. Coiling of stigmas.
127. Sympetalous condition of corolla, the original free petal condition still represented by the vestigial corolla lobes.
128. Tubular shape of corolla.
129. Texture of corolla.
130. Zygomorphic corolla with strap-shaped condition.
131. Centripetal split of the inner sides of the corollas, giving radial symmetry to the head.
132. Yellow color of corolla.
133. Outer ligulate corollas with broad purplish band beneath, the inner ones without such band.
134. Characteristic stamens with delicate filaments.
135. Sagittate anthers.
136. Union of stamen filaments with corolla.
137. Union of anthers, or synantherous condition.
138. Characteristic pollen grain.
139. Color of pollen.
140. Minute pedicel of flower.
141. Pappus development, replacing calyx.
142. Characteristic simple nature of individual pappus bristles.
143. Nectar gland in flower.
144. Characteristic nectar excreted.
145. Complex leaf reaction during the ontogeny, giving a succession of leaf types.
146. Juvenile leaf shape.
147. Lobed leaf type of the older plant.
148. General size of leaf.
149. Characteristic texture of leaf.
150. Characteristic leaf margin.
151. Soft narrow teeth on the lobes.
152. Flat, sheathing leaf base.
153. Lactiferous vessels.
154. Secretion of latex with bitter principle.
155. Margined petiole.
156. Hollow peduncle or scape.
157. Characteristic texture of the peduncle.
158. Property for great elongation of the peduncle in suitable environment to three feet or more.
159. Hollow petiole and midrib.
160. Delicate hairs on the leaf blade.
161. Long silky hairs at base of petiole.
162. Characteristic shape of roots.
163. Characteristic texture of roots.
164. Branching of roots.
165. Special longitudinal segmentation of the old main root.
166. Special reproductive ability of roots, any little piece being able to develop a new plant.
167. Root hairs on root tips.
168. Fruit an achene.
169. Development of parachute neck or strand at top of achene.

170. Shape of mature achene.
171. Characteristic texture of achene wall.
172. Prominent conical beak on the achene.
173. Special ribs and grooves on the achene.
174. Prominent projections, especially at the upper part of the achene.
175. Color of achene.
176. Hygroscopic closing and opening of pappus bristles in wet and dry conditions.
177. Shape and size of stem.
178. Slow growth of stem producing the leaf rosette.
179. Characteristic cortical region of stem.
180. Definite physiological gradient in the growing bud giving five kinds of stem development in succession: 1, the rosette stem; the peduncle; 3, the disk; 4, the pedicel; 5, the cortical stem tube from which the ovulary is developed.
181. Special vascular system in the rosette stem.
182. Arrangement of vascular bundles in the peduncle.
183. Vascular supply in the expanded disk.
184. Nature of the vascular system in the pedicel.
185. Characteristic spiral phyllotaxy in the rosette.
186. Spiral arrangement of flowers on the disk.
187. Closing of flower heads in the dark and in low temperature.
188. Potentiality interfering with complete sexualization of chromosomes, producing imperfect synapsis at reduction.
189. Irregularity of reduction in the anther.
190. Regularity of partial synapsis in the ovule, giving rise to diploid megaspores.
191. Characteristic shape and size of the one functional megaspore, with dissolution of the three vestigial megaspores.
192. Characteristic diploid female gametophyte arising from the diploid megaspore.
193. Characteristic egg apparatus with diploid egg.
194. Parthenogenetic development of the diploid egg.
195. Interference with Mendelian hereditary transmission because of diploid parthenogenesis.
196. General nature of endosperm development.
197. Characteristic mature embryo sporophyte.
198. Characteristic sprouting of the seed.
199. The character of the seedling cotyledons.
200. Potentiality to produce anthocyanin, especially in the young plant.

SUMMARY OF ACCUMULATION OF POTENTIALITIES IN THIRTY-FOUR SPECIES OF PLANTS

NAME OF PLANT	GENERAL POTENTIALITIES	SPECIAL POTENTIALITIES	TOTAL
Nitrosococcus nitrosus Mig	10	6	16
Rivularia echinulata (Smith) B. & F.	11	22	33
Scenadesmus quadricauda (Turp.) Breb.	17	11	28
Sphaerella lacustris (Girod.) Wittr.	21	21	42
Spirogyra reflexa Trans	21	18	39
Puccinia graminis Pers	26	29	55
Dictyophora phalloides Desv	26	32	58
Chara crassicaulis Schleich	30	32	62
Polysiphonia variegata (C. Ag.) J. Ag.	29	35	64
Riccia fluitans L	38	30	68
Frullania asa-grayana Mont	39	41	80
Archidium ohioense Schimp	40	35	75
Polytrichum commune L	45	40	85
Ophioglossum vulgatum L	59	36	95
Onoclea sensibilis L	60	45	105
Equisetum arvense L	60	51	111
Marsilea quadrifolia L	69	53	122
Selaginella krussiana (Kunze) A. Br.	70	55	125
Cycas revoluta Thunb	84	59	143
Zamia integrifolia Ait	84	65	149
Araucaria araucana (Mol.) K. Koch	83	57	140
Taxodium distichum (L.) Rich	84	69	153
Pinus radiata D. Don	83	88	171
Ephedra viridis Cov	85	95	180
Echinodorus cordifolius (L.) Gris	99	71	170
Vallisneria spiralis L	100	80	180
Zea mays L	100	85	185
Iris germanica L	100	89	189
Tipularia unifolia (Muhl.) B. S. P.	100	92	192
Magnolia acuminata L	98	72	170
Viola papilionacea Pursh	99	84	183
Salvia pitcheri Torr	100	86	186
Salix interior Row	100	85	185
Taraxacum officinale Weber	100	100	200

BOOK REVIEWS

Modern Genetics

The development of modern genetics has brought increasingly close relationships between the facts of heredity and the fields of evolution, embryology, cellular biochemistry and cytology. The author of the present volume, believing that these relationships rather than the mere mechanics of Mendelian segregation should be the theme of genetics text books, has written a text with this in mind. Mendelian inheritance itself is given short shrift in a few pages: perhaps too short for the elementary student. Then follow very fine discussions of the chromosome cycle and its modifications, the behavior of individual chromosomes, the linear differentiation of chromosomes, including an excellent account of crossing over and chiasmata. The foregoing topics comprise Part I. Part II considers the facts of embryology and their relations with genes and gene interactions. Part III is devoted to genetics and evolution, with up-to-date discussions of species formation, selection, cytoplasmic inheritance and related topics. Part IV takes up genetics and human affairs, including plant and animal breeding and a modern discussion of human inheritance. Part V is given over to a discussion of the nature of the gene. Here are discussed such topics as cellular biochemistry, effects of radiation, position effects, rate and causes of mutation, and estimates as to the size of the gene. The book is well illustrated and the references are frequent and modern. Teachers of genetics will find the book invaluable, but it appears to be somewhat in advance of the usual elementary genetics class. Perhaps beginning courses in genetics should be geared to this higher rate of progress. The book can be unreservedly recommended for advanced classes. A short appendix gives a concise account of methods of using Drosophila in class work. A surprising number of grammatical errors mars the otherwise pleasurable reading of the volume.—*L. H. S.*

An Introduction to Modern Genetics, by C. H. Waddington. 441 pp. New York, the Macmillan Co., 1939. $4.00.

A New Genetics Textbook

The new genetics text, "An Introduction to Genetics," by Beadle and Sturtevant, is unique in several respects. Of the twenty-three chapters, thirteen are devoted to a discussion of the ordinary behavior of chromosomes and hereditary factors. Five chapters are given over to a discussion of the various types of chromosomal aberrations and polyploidy. A separate chapter is devoted to each of the following topics: position effects, species differences, extra-chromosomal inheritance and material influences, genes and phenotypes, and a historical outline of genetics.

The order of presentation is most unusual. The first two chapters deal with sex chromosomes and sex-linked factors. Mendel and autosomal inheritance not being mentioned until the third chapter. Chapters on inversions and incomplete chromosomes precede the chapters on lethals and multiple allels. Special emphasis is placed upon both normal and abnormal chromosomal behavior, with abundant references to Drosophila and maize. A full page plate illustrates nine eye colors in Drosophila, and two other page plates show excellent photomicrographs of both normal and abnormal chromosomal configurations. Diagrams are numerous, but only a few photographs are included. There are problems at the end of each chapter. Probability is discussed in the appendix.

The reviewer gained the impression that the title, "An Introduction to Genetics," is a misnomer, as the book is too technical for the beginning student. Very little is said about human heredity, and the simpler modern statistical techniques, such as chi-square, are not mentioned. The book should be a valuable reference for advanced students in genetics, especially those primarily interested in Drosophila and chromosomal phenomena.—*D. C. Rife.*

An Introduction to Genetics, by G. W. Beadle and A. H. Sturtevant. xxiii + 391 pp. W. B. Saunders Company, Philadelphia, 1939.

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